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INJECTORS AT THE CENTENNIAL.

OUR illustrations represent the Friedmann Injectors, and the methods of their application. This injector is exhibited in the pump annex of Machinery Hall, by Messrs. Nathan & Dreyfus. Its distinguishing features are that it has no movable parts, and is provided with an intermediate nozzle by which the water supply is conducted in two annular streams to the condensing chamber of the injector, where the steam jet is subjected to the action of both, at separate points. The result of this double action is the complete condensation of the steam jet, and the transfer of its inherent power and velocity to the water united in one column, and projected into the boiler.

Having fixed nozzles, and no movable parts, the wear is reduced to a minimum, and the annoyance due to making joints, or packing parts, is removed. These injectors are divided into two kinds—the lifting, and the non-lifting. Figs. 1, 2, and 3 show the design and construction of the non-lifting, and Fig. 4 that of the lifting injectors. Fig. 5 illustrates, on the right, the method of attaching that shown in Fig. 3, and on the left that shown in Fig. 4, to a stationary boiler; while Fig. 6 illustrates the manner of attaching that shown in Fig. 1 to a locomotive engine.

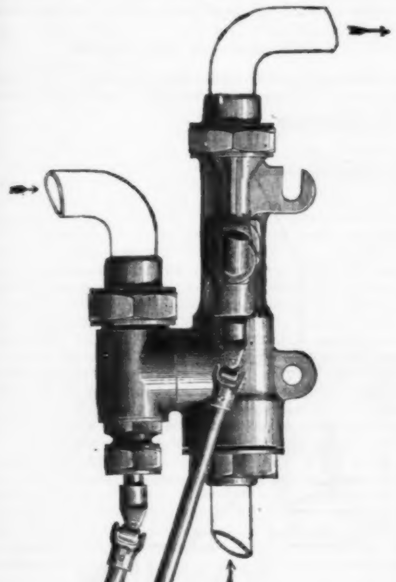


FIG. 1.

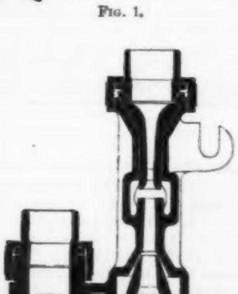


FIG. 2.

In a report presented to the Master Mechanics' Association, by one of its committees, we find the following averages taken from the results of 16 trial trips, eight of which were made using pumps, and eight using these injectors. Trials with pump: total time on the road, 13 hours 50 minutes; running time, 7 hours 51 minutes; speed, 17 miles an hour; cars hauled, 22.85; pounds of coal, 9529; pounds of water, 48,888; evaporation per lb. of coal, 5.14; steam pressure, 113. Trial trips with Friedmann injector: total time on the road, 12 hours 52 minutes; running time, 7 hours 42 minutes; speed, 17.21 miles an hour; cars hauled, 22.31; pounds of coal, 8736; pounds of water, 46,826; evaporation per lb. of coal, 5.36; steam pressure, 113. The engine used had cylinders 16 inches diameter and a 24-inch stroke, with driving wheels 5 feet in diameter, and weighed 67,900 lbs. The length of each of the sixteen trips was 128 miles. The saving here reported in favor of the injector amounts to about 9 per cent.

We have no space to here further allude to these experiments, more than to say that they are both interesting and instructive. The Friedmann injector is a German invention, and is largely employed upon locomotives, especially in Europe.

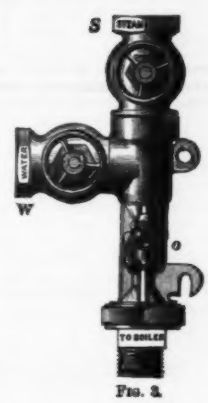


FIG. 3.

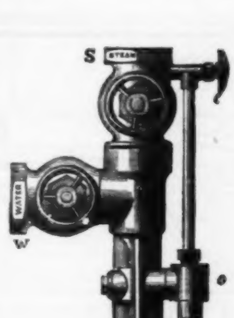


FIG. 4.

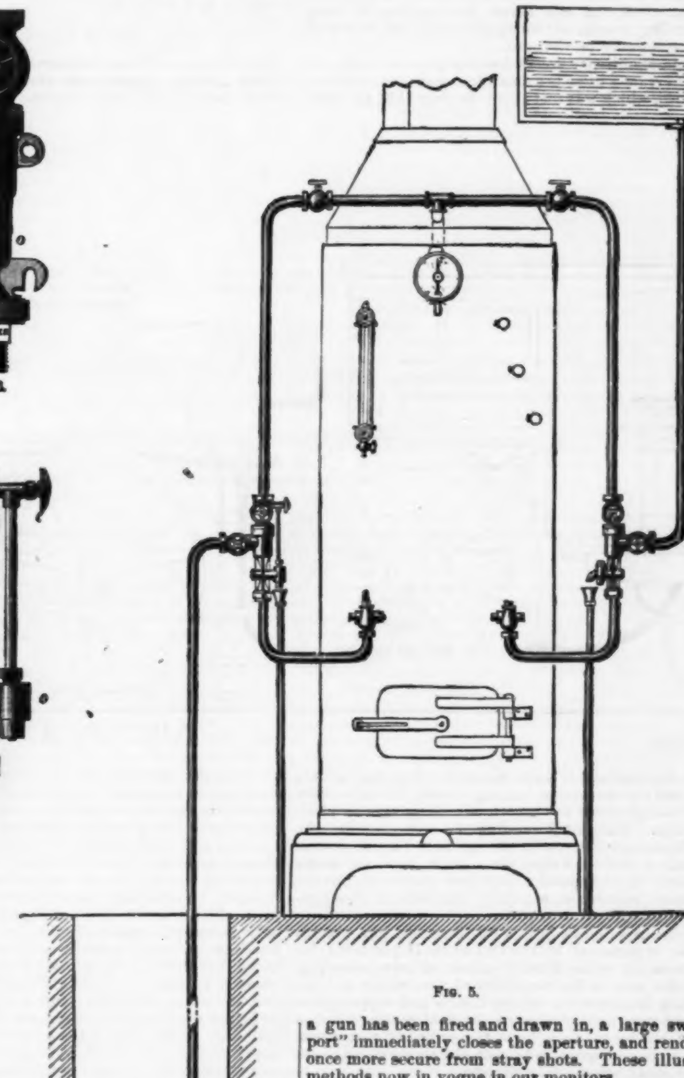


FIG. 5.

THE NAVY DEPARTMENT AT THE EXHIBITION.

THIS occupies the southeast end of the Government Building, and is classified under eight separate heads, namely, Ordnance, Steam Engineering, Construction and Repair, Yards and Docks, Medicine and Surgery, Equipment and Recruiting, Provisions and Clothing, Hydrography, including details of Arctic Exploring Expeditions, Astronomical and Naval Observations. These are each represented by display of the distinct manufactures implied in their titles; the design being to illustrate systematically the definite objects and workings of each section in its immediate relation to the United States Navy.

NAVAL ORDNANCE.

Commencing in the order of the above category, the first collection is that of naval ordnance. Considering the transitional aspect presented by the various forms and methods of all artillery, this must not be regarded as a complete display of what is now in use, but it accurately represents the various armaments of our own ships, and the manner of putting up ordnance and its appendages on shipboard, since the first authorized gun was discharged in the Revolutionary contest by Commodore Abraham Whipple. This collection is supplemented by some yet older relics, with which we shall acquaint the interested reader in due course.

On the elevated earthwork around the left side of the main entrance to the building a battery has been set up, which includes a *fac simile* of a monitor turret, and although this is constructed of light plates, and the interior of wood, yet it is perfect in form and every other respect, being made after the plans of Captain John Ericsson, of New-York. The only apertures by which an entrance can be effected are the portholes, but the exertion is amply repaid by an examination of the contents.

There are two 15-inch guns, each about 17 feet long, weighing respectively 43,618 lbs. and 43,610 lbs., without the carriages. One of the guns is mounted on Ead's carriage, by which it is run out and otherwise regulated by steam. The other is on the Ericsson carriage, and is worked by hand power, taking the united efforts of four men to direct its movements. (Inside the building is a model showing the manner of checking the recoil of these Ericsson guns.) After a gun has been fired and drawn in, a large swinging "false port" immediately closes the aperture, and renders the turret once more secure from stray shots. These illustrate the two methods now in vogue in our monitors.

Outside the turret are arranged the standard cored, solid, shrapnel, and canister shot used for the guns within. Next are the following guns: an 8-inch rifled gun altered from a smooth-bore, and weighing 17,275 lbs., mounted on the new pattern iron pivot carriage; a 9-inch smooth-bore gun, weighing 9186 lbs., mounted on the Marsilly iron carriage; one 8-inch smooth-bore of the same style, weighing 6478 lbs.; one 11-inch smooth-bore, weighing 15,844 lbs., mounted on the rather clumsy Grice wooden carriage; one 60-pounder rifled Parrot gun, weighing 5390 lbs., on the new ordnance carriage for pivot or broadside, and used for both; one 100-pounder gun of same sort, weighing 9757 lbs., mounted on Ericsson's patent iron pivot carriage, the advantage of which is that one man can run this great weight in and out with ease; one 11-inch smooth-bore, mounted on the Ericsson iron carriage; one 32-pounder smooth-bore gun, weighing 4560 lbs., mounted on iron broadside carriage; one 20-pounder brass rifled boat howitzer, and one smooth-bore of the same calibre; one new pattern rifled Cochrane gun; one Moody breech-loading gun, and a gun-carriage of Ward's design, and a light one for a 12-pounder. There are also exhibited three specimens of old-fashioned carronades used in the war of 1812. Under each of the above guns are arranged the various death-dealing projectiles for them, including solid shot, shell, grape, shrapnel, and canister. Near this part of the collection are two boats of historical interest. One is a large flat-bottomed craft made by Captain Buddington from the cabin

of the "Polaris," and in which he and his companions made their perilous escape from the Arctic regions. The other, a smaller boat, is the "Faith," used by Dr. Kane in his similar explorations. In connection with these relics mention may be made of photographs and sketches in the corresponding section of the building, showing the Buddington party constructing the boat on the ice, with the ill-fated "Polaris" frozen in close by.

Entering the building, the first objects to be examined are the Gatling guns or mitrailleuses. There are two of these shown, which, on close observation, prove slightly different. The gun is composed of six barrels, a hand crank causing them to revolve about a central axis parallel to their bores; as each barrel comes opposite a certain point, a self-primed, metal-cased cartridge falling from a hopper, is pushed into the breech by a plunger, where it is exploded by the firing-pin. The machinery is simple, and not liable to get out of order, and the gun can fire 200 shots a minute, with long range and precision. The weight of the Gatling gun is about 1000 pounds, and is therefore very great compared to that of the charge, so there is little or no recoil, and when once pointed it requires hardly any adjustment. The distinction between the two on exhibition is in the form of the hopper. That first designed was permanent and of a circular form, and being of light material, a good blow would render it useless. But the newly designed hopper obviates this difficulty. It is a single case, and as soon as the charges in it are expended, it is replaced by a fresh one, of which a large stock is carried in the ammunition boxes. Now we can make several comparisons with other guns in the collection having many or revolving barrels, in order to appreciate the rapid strides made in this direction of late years.

The first is an old Billinghurst battery, which was used during the civil war. It is composed of 25 parallel barrels, which, being fixtures, do not scatter the shot like the Gatling. Another for like comparison is a De Brame gun, which consists of six revolving chambers and one barrel having an open rifled twist to give direction to the ball.

Then there is also a light, revolving Nugent gun, worked with a crank and lever, intended for the bow of a gunboat. Having six chambers and one barrel, the rapidity of firing heats the latter very much, so two spare barrels are sent with each gun, and can easily be changed.

We next come to ordinary breech-loading guns for boat service. Prominent among these is a small iron gun obtained from Alvarado, Mexico, which was cast about the year 1490, and used by Cortez in his conquest of that country. It is very primitive in form, and the method of loading it is by lifting out by hand a heavy weight from the breech, which is kept in place by a side wedge. Turning from this we may examine the light 3-inch brass howitzers, with the intricate French system of breech-loading and elevating, or a more serviceable one still, in the form of a 12-pounder Dahlgren gun, with the old style of elevating apparatus, which is less liable to derangement than any other.

Near these is a new 3-inch breech-loading rifled gun, recently made as an experiment by the Ordnance Department, being an improvement on the French system of breech-loading. The forte of this gun is the simplicity of the wedge and the rejection spring for throwing out the discharged copper cylinder. All these guns are mounted on the field carriage, but of course, when on board, they have the ordinary permanent ones. With each gun may also be seen the ammunition chest, passing-boxes, drag-ropes, etc., complete.

SMALL ARMS AND RELICS.

The array of small arms is very interesting, and shows old flint, rifles, and carbines, pivot-guns, musketoons, muskets, sabres, Bowie-knives, cutlasses, broadswords, revolvers, pistols, and frogs, from the revolutionary times to the more improved Martini-Henry breech-loaders and sabres of to-day. To enumerate them in detail would occupy volumes, but to him who will take the trouble of reading the labels on each, they will prove an endless theme for reflection. They carry us back to the times when the night-watch paraded even our own streets with shouldered pike and lantern, or to the medieval times in Old England, when the clash of a sword in the street at night would cause the heaviest sleeper to awake and sally forth from the watch-house, hoping to win his spurs and cover himself with glory and renown.

There are indeed relics of historical interest enshrined in this Government Building. In a case by themselves are the old cutlass, boarding-armor, and helmet used by Captain John Paul Jones on the "Bonhomme Richard," while the identical flag which floated from the fore-top of that gallant ship forms an appropriate drapery around the portrait of her commander on a pillar close by. Again, we have also an old musket, tomahawks, bowie-knives, and pikes taken by divers from the wreck of the monitor "Keokuk," off Charleston. There is also a case containing hand-grenades, pistols, etc., in pieces, to illustrate the many parts of which they are composed.

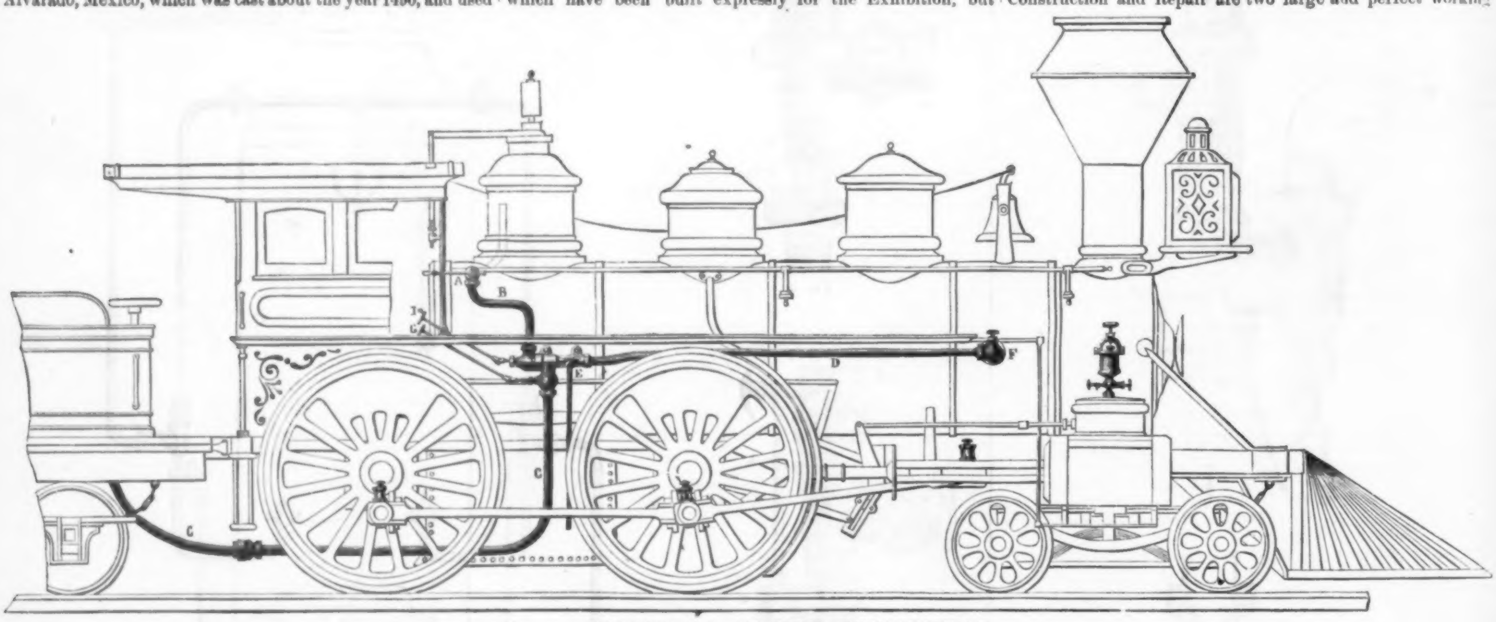


Fig. 6.—INJECTORS AT THE CENTENNIAL.

PROJECTILES.

Now we will examine the projectiles for all these guns, and the array is indeed formidable. Dahlgren's hollow shot varies in size from 20 to 150 pounds; shell from 12 to 50 pounds, and steel bolt shot from 30 to 150 pounds. There are the shot, shell, shrapnell and canister for smooth and rifled bore guns of all the best makes and inventors, including Holroyd, Parrott, Schenkl & Sawyer, Stafford, Smith, Emory & Ganster, and to show the interior of these projectiles is a table, on which are arranged all classes of shot in sections, some fired at iron targets, others of tempered steel, wrought iron, cast iron and cored. In another case are nearly all the pieces of a shell which were collected after it had exploded. On shelves are arranged the passing boxes for the various charges, for each charge must have a box of its own.

Gunpowder is represented in every conceivable form, from the very fine musket powder to the pebbles for big guns, some of which are an inch in diameter. It will be observed, also, that these pebbles are of various shapes—octagonal, hexagonal, grape and square. They are made from fine powder, pressed, and experiments are constantly being made at the experimental battery at Annapolis, to test the efficiency of the various kinds and forms.

Next in order is a table containing models of projectiles, guns and gun carriages, showing the manner of closing and opening ports of vessels, the system of loading by steam, and, as previously mentioned, the way in which the recoil is checked of Ericsson's heavy guns. Then there is a table on which are exhibited the various equipments of a powder magazine, including dust pans, hammers, etc. These are all of copper, no other metal being allowed in a magazine, for fear of friction or contact creating sparks. And so stringently is this rule enforced, that even the shoes worn by men in the magazine are special ones, of canvas and leather sewn by hand, without a nail in them. There is also a copper lantern which reflects light into the magazine through a powerful lens in the wall.

STEAM ENGINEERING.

The Bureau of Steam Engineering is next in order, and includes marine engines and their appurtenances, none of which have been built expressly for the Exhibition, but were simply selected from stock and erected with a view of showing, as nearly as possible under the circumstances, the position in the ship occupied by the engines. By this display an accurate idea can be formed as to how low, in a wooden gunboat or ironclad vessel, engines of this class have to be placed in order to avoid injury from shot or shell. The larger of the engines on exhibition were built for the ship "Nipsic," now being reconstructed at the Washington navy yard. These are condensing engines of the compound type, only recently introduced into the service, and are of eight hundred nominal horse power, which means, of course, about one-third their actual power. They have a high-pressure cylinder, 34 inches diameter; a low-pressure cylinder, 51 inches diameter; and a stroke of 42 inches. The principal weights are: Condenser, 23,500 lbs.; high-pressure cylinder, 17,250 lbs.; low-pressure cylinder, with steam chest, 21,000 lbs.; the channel plate castings, containing air and circulating pumps, weigh about six tons each, and the centre framing of the engines about three and a half tons each. The valve stems, links, reversing shaft, arms, suspending links, eccentrics, with rods and straps, handles of water valves, and starting gear, etc., are all highly polished, and present a very beautiful and symmetrical appearance.

So compact is it in all its details, that 160,000 pounds of machinery is believed, in this instance, to have been condensed into about as small a space as possible. The boilers for supplying steam to the engines of the "Nipsic" are eight in number, but only two are exhibited, in order to show the style and quality of workmanship. These are of the compound type, each 8 feet diameter by 8 feet long, and contain one hundred and thirty 2½-inch brass drawn tubes; each weighs about 8½ tons, and is calculated to carry a working pressure of eighty pounds to the square inch. They are all fitted with Ashcroft's patent doors and bars.

The second set of engines were built for the proposed ship "Epervière," which was designed at the close of the civil war by the late Chief of the Bureau, B. F. Isherwood, but were not constructed, as no appropriation was made for that purpose. The engines are very proportional in design and of 500 nominal horse-power. They are known as the back-acting type, and have cylinders 36 inches in diameter, with a stroke of 48 inches. All the working parts are of Bessemer steel, and are placed so that the joints and stuffing-boxes can easily be reached from the engine-room while the engine is in motion. The total weight is about 120,000 pounds.

There are also two specimens of vertical engines and boilers for screw cutters, together with detailed drawings; also specimens of screw propellors for steam launches. Next is exhibited Baird's distilling apparatus for making condensed water pure. In these the steam is admitted from the boilers into the condenser and there condensed, after which it flows by action of gravity down through the filterer, at the same time being aërated, and passing off as cool, pure water. There is also exhibited Seldon's apparatus for purifying feed water, which is saturated with mineral and other deleterious substances, with a view of stopping the corrosion usually attendant upon the use of surface condensers. By Seldon's method the water passes through screens first, then through charcoal and lime or soda—the quality of the water determining which. The system is thoroughly successful, and is in use on the coastwise steamers and in Hecker's Flour Mills, New-York. Connected with this display are shown a specimen of the portable forge furnished to the navy; U. S. standard fire hose; details of the engines on exhibition, consisting of clock, engine register, steam and vacuum gauges, lamps of various kinds, drip pans, oil feeders, and the various wrenches used about machinery. In another place are a model of the machine used by the navy to bend chain cable links; the indicating instruments for terminating the efficiency of the engines; hydrometers for ascertaining the concentration of water in the boilers; specimens of gum valves and packing; engine cloths, etc., as used on the Government ships. Also portfolios, which may be examined on application to one of the attendants, containing the detailed drawings of the "Nipsic's" engines, a log-book of the data taken on board ship in connection with the operations of the engines, showing the consumption of coal, oil, etc., together with a synopsis of the quarterly log as furnished to the Navy Department. Lastly, there is an old log-book of the schooner "Nancy," dated 1790, and a curious letter, dated November 13th, 1774, from one Isaac Smith, of Boston, to Captain Harding, then of the sloop "John," lying at Gloucester, ordering the latter to dispose of the cargo he had, and to buy another of molasses or sugar, and urging him to study economy both ways. This makes altogether an unique and interesting display of its class, well worthy of careful examination and study.

CONSTRUCTION AND REPAIR.

The principal exhibits under the auspices of the Bureau of Construction and Repair are two large and perfect working models of the man-of-war "Antietam." The first is about 50 feet long from the end of jib to the spanker boom, and was sent in sections from the Naval College at Annapolis, where it has been used as a drill ship for the cadets. It is a most interesting addition to the collection, and is believed to be the most complete model ever made. The next is a smaller model of the same ship, showing it on the ways ready for launching. In another place is a finely finished wood model of the hull of a sea-going monitor of 9300 tons, having an enormous ram, recently designed by S. H. Pook, naval constructor at the New-York yard. Also similar models of the hulls of the United States ships New Ironsides, Hartford, Kearsarge, Mississippi, Monadnock, Vandalia, Niagara, Ohio, Portsmouth, Enterprise, Washington, St. Mary's, Constitution, Fulton, Jamestown, President, two sloops-of-war, of 3500 and 1200 tons respectively; two torpedo boats, and the gig of the Lackawanna; also, a model of the U. S. S. Merrimac before she was converted into an iron-clad. The old method of making the knees of a ship was by selecting a tree having an appropriately bent bough, and utilizing that. It was expensive, because it usually took one tree for each knee, but an employé in the Charlestown Navy Yard invented a plan for bending to the required form a heavy, straight piece of oak, after which the necessary angle is fitted to it. Two of these knees are exhibited, and it is hardly necessary to add that the new process is a very economical one.

YARDS AND DOCKS.

The next section is that of the Bureau of Yards and Docks, and includes very interesting and well-made models of the dry docks of the U. S. Navy at Brooklyn, N. Y., and Charlestown, Mass., with plans of the buildings and machinery in the yard at the latter place; also, of the dock at Norfolk, Va., with a model of a monitor inside, and one of the Mare Island Navy Yard, Cal., which is not yet completed. There is also a pyramid consisting of nine blocks of wood cut from various old ships of the navy when under repair or being broken up.

MEDICINE AND SURGERY.

This bureau has contributed articles to the collection with a view of showing the necessary outfit and furniture used by a surgeon in the navy. It also illustrates, by means of models, the way in which the sick and wounded are cared for on United States vessels. The collection includes drugs, medicines, wines,

nutritives, sugar, etc., bottled and put up in the peculiar fashion necessary to stand sea voyages; a complete set of dispensary furniture for a ship carrying 500 men; cots, showing the manner in which wounded men are transported; a series of record and account books for a naval hospital; the various washbowls, china, etc., used in the navy, together with a surgeon's outfit of stationery and a very fine set of instruments, etc. The models of hospital ships are two in number: the first is of the U. S. S. "Idaho," which was converted into its present form and stationed at Yokohama, Japan, and the second is of the fore part of the U. S. S. "Hartford," showing the sick bay therein. These models are in sections, and the interior arrangements are most perfectly shown. Connected with this department are also about thirty photographs of the different National Homes in the United States for disabled sailors and volunteer soldiers.

EQUIPMENT AND RECRUITING.

Under this head there are two ships' galleys, with all culinary utensils complete; one is capable of cooking for 500 men and the other for 200. Next is a small standard boat stove for 20 men; a large wooden fan for ventilating the lower part of ships in hot weather. Stationery is also included, and of that there are samples of all the books and blanks used on shipboard, and one case contains the mess kettles, tin pots, and sewing outfit of a seaman. A library is sent with every ship, and although not extensive, yet the one exhibited will show the class of literature appreciated by the sailor. In various parts of the department are lay figures of sailors in the uniforms and arms of 1776, with old boarding pike, powder barrel and match stave; a marine private of the same date; sailors of 1797, 1800, 1805, 1815, 1816, 1835, and a marine sergeant and quartermaster of 1876. The visitor who will examine these costumes seriatim can not fail to observe how we have improved in taste and personal appearance during the century. Not only is the sailor's dress of to-day neater, and consequently more elegant, but there is a manly and graceful *tout ensemble* about the present Jack Tar which certainly did not characterize the mariner of old.

The Charleston Navy Yard has contributed to this section a complete section of manilla and hemp rope made there; also a 25-inch ship's cable, of which the breaking strain is 125 tons, and a series of wire ropes, from 6 inch to ⅜ of an inch, used for permanent stage.

All bunting used in the navy must sustain a strain of 45 pounds, otherwise it is rejected. To test this a machine is used, and one of them is exhibited. It consists of the simple lever and weight, and grips the bunting between two jaws while the weight is moved gradually to the required standard. Several samples of bunting are exhibited, and one of these, which was tested in our presence, broke at about 48 pounds, showing it to be a little over proof. In the case with the bunting are shown samples of Coston's night signals to burn six or eight seconds. These are held and fired by a pistol-like instrument, also shown. In another case may be seen the other signals used in the service, consisting of rockets with balloons, serpents, stars, gold rain, solidified Greek fire, warning signals and signal shells, and a semaphoric telegraph lamp with calcium light reflector. All these signals have different meanings when used at sea, according to their color, sort and the number, and other vessels seeing them can read them as accurately as the alphabet.

The display of flags is most interesting. There are two of the old pine-tree flags and a grand union flag of 1776, union national flag of 1777—the latter is a white flag with an anchor, and the word Hope on it, the field is blue, and has thirteen white stars; another union national flag, with stars and stripes, of 1795; union national flags of 1815, 1818 and 1876; also our union jack of to-day. Next are arranged the commodore's blue, broad pennant from 1776 to 1860, red pennant from 1776 to 1876, and white pennant of the same date; also the flag-officer's blue, red and white flags from 1858 to 1863; a rear-admiral's blue flag, a rear-admiral's red flag (these with two white stars), and a rear-admiral's white flag (two blue stars) from 1866 to 1869. An admiral's and vice-admiral's flags during the same years are also shown—the former is blue, with four stars in centre, and the latter has three stars. The flag of the Secretary of the Navy is also shown. It is blue, with a white anchor and four stars in the centre. In addition to these is a complete series of officers' flags, pennants and signals of to-day, the name of which is appended to each.

PORTRAITS OF NAVAL OFFICERS.

The portraits of distinguished naval officers are numerous. Among the more prominent may be mentioned: Commodore Abraham Whipple, who commanded the privateer "Game Cock" before the Revolution, with which he captured twenty-three French prizes during the war between that country and England. He received a commission from Congress, and, as before observed, discharged the first authorized gun in the contest for Independence. While commanding a squadron and trying to save Charleston (S.C.) from capture, he rather ingloriously terminated his naval career by losing his squadron. He necessarily retired into private life, and died in 1819.

The next portrait is that of the celebrated Captain John Paul Jones, and this is followed by one of Commodore Esek Hopkins, the first Commander-in-Chief of the Continental Navy, who was commissioned by Congress in 1775; Commodores R. Dale, William Crane, D. T. Patterson, Rear-Admirals S. F. Dupont and Andrew H. Foote, Admiral W. B. Shubrick, Com. Rogers, Rear-Admiral Henry H. Bell, Commodores Jacob Jones, George Read, James Biddle, and Downes, Rear-Admiral John A. Winslow, Commander of the "Kearsarge." Below the latter's portrait is appropriately placed a piece of timber taken from his gallant ship when it was being repaired. Next are portraits of Commodores M. C. Perry, Wolsey, John B. Nicholson, Isaac Hull, Admiral D. G. Farragut, Commodores Louis Warrington, O. H. Perry, Daniel Porter, Isaac Chauncey, John T. Newton, Captain L. Kearney, Purser Samuel Hambleton, Paymaster John M. Hambleton, Surgeon Evans, Commodore Preble, Rear-Admiral Stewart, Commodores Macdonough, Decatur and Bainbridge.

The Bureau of Provisions and Clothing exhibits a complete set of sailor's kit, and in another case are samples of beef, pork, bread, rice, etc., used on shipboard, together with a set of steward's stores.

HYDROGRAPHY—ARCTIC EXPLORATIONS.

Under this head of hydrography are included accounts of Arctic exploring expeditions, and astronomical and naval observations. The first relics shown are those of Dr. Kane in his expedition of 1853. Here we will give an epitome of the voyage and its results in order that the visitor may appreciate more fully the value of the collection. In the spring of 1853, four Arctic expeditions set out, three of which were English, but the fourth and most important was that fitted up chiefly by Mr. Grinnell, of New-York, and Mr. George Peabody, of London. This was commanded by Dr. E. K. Kane, who acted as surgeon, naturalist, and historian of the former Grinnell expedition under De Haven. He sailed from New-York in the "Advance," May 30, 1853, determined to penetrate as far up Smith Strait as possible, in the hope of discovering an open polar sea and of finding tidings of Sir John Franklin. He entered ice early in August, and then commenced to explore the coast in boats, discovering and naming before the following spring several capes and other remarkable natural features. They thus continued until illness and the severity of the climate compelled them to abandon the brig in boats and sledges on May 17, 1855; and after much privation and many narrow escapes they reached the Danish settlement at Uppernavik, August 9. Here they were picked up by the United States ships, under Captain Harstene, sent out in March of that year and returning to this country in the fall of 1855. In a scientific point of view, Dr. Kane's expedition attained most important results. These are summed up by himself in his report to the navy department of the United States:

1. The survey and delineation of the north coast of Greenland to its termination by a great glacier.
2. The survey of this glacial mass and its extension northward into the new land named Washington.
3. The discovery of a large channel to the northwest, free from ice and leading into an open and expanding area equally free. The whole embraces an iceless area of 4200 miles.
4. The discovery and delineation of a large tract of land forming the extension northward of the American continent.
5. The completed survey of the American coast to the south and west, as far as Cape Sabine; thus connecting our survey with the last determined position of Captain Inglefield, and completing the circuit of the straits and bay heretofore known at their southernmost opening as Smith Sound. The relics exhibited of this expedition consist of his complete fur suit, rifle, a portion of Dr. Franklin's boat, Dr. Kane's own boat, the "Faith;" instruments, log-books, journals, sketches by himself and others, and the silver and gold medals presented to him by Her Majesty Queen Victoria.

The next series of expeditions illustrated here are those of Captain Charles F. Hall and his successor in command, Captain Buddington. Captain Hall's first explorations were carried on alone from 1860 to 1869, during which time he discovered among other things some traces of the expedition under Frobisher, three hundred years before. But in June, 1871, he sailed from New-York, with a well-selected corps of assistants, in the schooner "Polaris," of over 400 tons. For nearly two years no important news was received from the explorers. In April, 1873, the British steamship "Tigress" struck an ice floe in latitude 53.35 north, longitude 35° west, on which were found Captain Tyson, one of Hall's officers, and eighteen others, who had been one hundred and ninety-six days on the ice, and drifted about two thousand miles. They reported that on October 15, 1872, the "Polaris" being fast in the ice about latitude 72° 35', and leaking badly, they had been ordered to land provisions, and, while so engaged, the floe broke up, and they were separated from the ship, and drifted southward without seeing her again.

They also reported that Captain Hall had just returned from a sledge expedition northward, when he was taken suddenly ill, and died October 8, 1871, and the "Polaris" was without boats when they left her. In the collection relating to this expedition is the boat before mentioned, which Buddington and party constructed from the cabin of the "Polaris" and escaped in, photographs and sketches of the ship boat, Captain Hall's grave, and some earth from his grave, sketches of the refraction of light in the Arctic regions, photographs of himself and dog and his Esquimaux servants, Hans and Joe. Also, Captain Hall's sword, flag and note books, and a model showing the construction and interior furniture and occupants of an Esquimaux mud hut. There are also the note books of Captain Tyson and Captain Buddington, while on their respective ice floes. Every relic here tells a story of its own. It is not only suggestive of patience, hardship, endurance bordering on rashness, and life nobly sacrificed in the search for truth, but the geographer, or he who loves travel and to read of travel, will find a strange fascination in these relics.

We next have in the same section maps and charts illustrating the various expeditions; a complete set of charts as furnished to United States vessels stationed in various parts of the world; folios of wind, current and thermal charts; water-color marine sketches by various officers; a few photographs of views, and one worthy of especial notice of the planet Saturn, from a drawing made by Mr. Trouvelot with a 26-inch refractor; photographs of this telescope, which is in the Naval Observatory at Washington. Next are samples of the French and American running lights and various other lanterns used on board; several specimens of patent logs, thermometers, etc.; an ordinary ship's binnacle and a very handsome bronze binnacle; a case containing the liquid navy standard compass and complete liquid boat compass, made by Richie, of Boston, and adopted by nearly all the large ships afloat; a tell-tale compass; an old-fashioned dry compass; the azimuth circle, magnet, card, case and other parts of a compass shown separately, in order to show how they are made; a sample of Professor Greene's binnacle compass, which, it is claimed, neutralizes the local deviation of compasses; an instrument by the same inventor for testing the accuracy of compasses issued to the navy, by rectifying the pivot centre, ascertaining whether the cap has any eccentric in it, and seeing whether the centre of the compass bowl has been decided true to its circumference. There are also several of Negus & Co.'s chronometers showing the mean time at Greenwich, and here; a break circuit chronometer, and an apparatus by Professor Eastman, for determining personal equation in astronomical observations; books on the latter subject. Captain Belknap's deep-sea sounding apparatus is also exhibited. With this the soundings are carried on with a light piano wire; the wire is made fast to a specimen cylinder and lowered. A shot is affixed to the cylinder, which detaches itself on striking the bottom, and at the same time the depth of water is shown on an indicator above. The cylinder is then drawn up, and brings specimens of mud, shells or other formations, from which the nature of the bottom is determined. In connection with this section are the houses outside the western portion of the building, containing the instruments used at the United States stations for observing the transit of Venus in 1874. They consist of a large transit telescope, a chronograph on which the observations of the telescope are recorded by electricity, a photographic camera, an equatorially mounted achromatic telescope, and other necessary levels, etc., while in the naval section of the building are the break circuit chronometer and sidereal clock, belonging to the transit instruments.

The former is similar to an ordinary box chronometer, except that on the second hand there is a toothed wheel, so arranged as to touch a spring at each second and thus break a galvanic circuit and actuate the pen of the chronograph by releasing the armature of an electro-magnet. The beginning of each minute is indicated by the break corresponding to that second being omitted. The clock is an ordinary astronomical clock, with gravity escapement, and also arranged to be put into connection with the chronograph. It is mounted on a large tripod field stand, and is protected by an outside casing, to prevent any changes of temperature from reaching the pendulum too rapidly and thus introducing secondary errors of compensation.

All the exhibits in the navy department are admirably arranged in their relations to each other, and can be studied consecutively with profit.

PRESERVED SPECIMENS OF ANIMALS.

This collection embraces some of the finest specimens of the wild animals of North America which can be obtained, and has been prepared with great care. It occupies a position at the eastern end of the section, and near the exhibit of the Springfield Arsenal. The bison or buffalo of the plains is represented by three fine specimens—one large bull and two cows. The specimens have been preserved with great skill.

North of these is a gigantic specimen of the white polar bear, with wide open mouth, made of carved and painted wood. Its coat is pure white, with the exception of one small spot on the right shoulder. The great breadth of chest, enormous limbs and long, sharp claws, fully bear out this animal's reputation for strength and ferocity. A little to the south is a grizzly bear from the Rocky Mountains, which is inferior in size and ferocity of appearance only to its Arctic neighbor. Near the southwestern end of the section is a group of smaller bears, embracing some very handsome specimens of the black bear, cinnamon bear and brown bear. The collections of ungalata, or horned animals, is very complete, and embraces specimens of the North American elk, barren and woodland caribous (belonging to the stag family), male deer, Virginia deer, peccary, mountain goat, moose, prong horn antelope, big horn sheep and moose. Among the fissipedia (those animals which have separate toes) are specimens of pumas, jaguars, ocelots, lynxes, wolves, foxes, fisher cats, martens, minks, wild cats, wolverines, skunks, otters, sea otters, bears (already described), raccoons, ferrets, sables, badgers, wolves, beavers and yaragundi. The rodents include specimens of squirrels, prairie dogs, marmots, beavers, porcupines, rabbits and gophers (rodents found in the Mississippi Valley and along the Missouri River).

MEANS OF PURSUIT AND CAPTURE.

The implements and apparatus for hunting are divided into: First, Hand implements or tools for striking, cutting and thrusting; second, Implements for seizure of objects, such as barbed implements, grasping lines (nooses), snares, thrown nooses and loaded lines; third, Missiles, including hurled weights, hurled sticks, hurled spears, slings and spears thrown by straps, missiles propelled by throwing sticks, bows and arrows, guns and accessories; fourth, Nets; fifth, Traps; sixth, Decoys and disguises; seventh, Methods of transportation; eighth, Personal equipments.

The collection of hand implements includes a highly interesting collection of clubs used by the Indians of the West and by the Northwest Coast Indians; knives of various patterns and sizes, including the stone and bone knives used by the Indians and Esquimaux; axes, tomahawks, cleavers and hunting spears. The implements for the seizure of objects embrace chiefly barbed spears for thrusting, used to a great extent by the Northwest Coast Indians. Some of these have fixed heads and others detachable heads. The collection of nooses is confined almost entirely to the lariats made of hair, hemp and cowhide by the Indians of the plains. There are also bird slings, used by the Esquimaux, and entangling lines, chiefly used in catching birds.

The collection of missiles is very complete and curious. It embraces, among other things, an interesting set of throw sticks, used by the Moqui Indians of New Mexico for hunting rabbits. These closely resemble the boomerang used by the natives of Australia, specimens of which are placed beside the throw sticks. There are also darts, lances, slings and a number of bows and arrows, the majority of which, however, are exhibited in the Indian and Ethnological collections. A complete collection of guns, including spring guns and air guns, smooth-bore guns, rifles and pistols, has been prepared by the proprietors of the *Forest and Stream*, and occupies a position in the northwest corner of the building. It is intended to be a complete representation of all the improvements made in guns for hunting, and includes accessories of loading, cleaning and repairing, sighting and testing fire-arms, together with appliances for carrying arms and ammunition. Under this group is embraced an interesting exhibit of gun cases and pouches of buckskin, powder horns, gun charges, gun-screw turners, saddles, stirrups of bone, gun flints, riding whips, etc., used by the Apaches of Arizona, and other Indians of the plains, and by the Northwest Coast Indians.

In the collection of hunting nets are rabbit nets used by the Indians of the Southwest, bird mesh nets, clap nets for birds, rabbit spring nets, and sieve nets for birds.

The various kinds of traps used in almost every section of the country are very completely represented, including specimens of steel traps used in catching bears, box traps for catching hares, foxes, squirrels, opossums, etc., and steel traps for catching rats, birds, muskrats; spring traps for catching hares, grouse, etc.; the log dead-fall used in the Mississippi Valley, fall traps for partridges, grouse snares, and fox trap made of bone, used by the Mahlemut Esquimaux.

One of the most interesting objects in this group is the bear spring used by the Northwest Coast Indians for hunting bears. It consists of a strong spring of whalebone tied with animal sinews, and covered with pieces of meat. Thus prepared, it is placed where the bear will be most likely to get it. The bear eats the meat, swallowing the spring with it. The sinews which hold the spring gradually dissolve, the spring unbends with great force and destroys the animal.

The exhibit of decoys and disguises is not yet complete, but a number of duck decoys used in hunting wild duck and lanterns for fire hunting and still-hunting are exhibited.

Methods of transportation are illustrated by specimens of snow shoes and saddles. Camp outfit is not represented, owing to the fact that this branch is already covered by the Hunters' Camp, situated on Lansdowne valley. The personal equipments of hunters are represented by a few specimens of clothing, boots and moccasins, and by a curious collection of snow goggles used by the Esquimaux. These generally consist of pieces of wood cut so as to fit over the eyes and with two narrow slits in them through which to see.

ANIMAL PRODUCTS AND THEIR PREPARATION.

Under this head are included: I. Preserved meats. II. Skins and their preparation. III. Manufactures from hard tissues. IV. Feathers and their application. V. Drugs, oils, chemicals, etc., manufactured from animal matter.

The collection of preserved meats is very complete, and embraces specimens of meat canned, pickled, smoked and desiccated. Among the specimens are dried lizards, dried grasshoppers, dried slugs and dried worms used by the Indians. There are also dried holothurians used by the Chinese of the Pacific coast. It was originally contemplated to have an exhibit of wool and hair in manufactured forms, but, owing to the immense display of these objects in the Main Building, the idea was abandoned. Brushes made of bristles and the hair of different animals are, however, exhibited.

The manufactures from hard tissues are fully exhibited by a variety of carvings of bone and ivory, and of specimens of horn and hoof implements. There are also specimens of tortoise shell, but no articles manufactured from the shell are as yet in place. Alligator teeth, which are used in the manufacture of jewelry, are shown. Deer, elk and moose antlers are placed on the columns supporting the roof, and give a picturesque effect to the appearance of the section. There are, as yet, but few specimens of feathers, but a collection of feather flowers from Florida is expected, which is said to rival the collection in the Brazilian section.

The skins of animals are also but imperfectly represented as yet, although there are already some fine specimens of bear, wolf, fox, sable, seal, otter and civet skins in place. A very fine collection of skins and furs, representing all the important fur-bearing animals, will be made by Hierpich & Co., of New York. There are also curious specimens of boots made from alligator hide, the skin of the rattlesnake, and from the skin of man, together with specimens of leather made from the skin of the boa and American bison. Birds are represented by the skins of the pelican and puffin used as furs.

The oils, chemical products, etc., exhibited include, as yet, only specimens of glue made from horns and hoofs of animals, several specimens of oil made from animal matter, perfume from the castoreum of the beaver, coloring matter from the hoofs of animals and from refuse human hair, pepsine and pancreatine, prepared from the stomachs of hogs and calves, ammonia from bones and horns, prussiates from hoofs, horns and leather waste, refuse from blood of slaughter houses, and a few other articles which are not yet in place. This department of the exhibits is still incomplete, and some important additions are to be made. On account of the necessary absence of Prof. Goode, for the past week, the preparation of the exhibits in the Animal Section has been much delayed, and it will be several days yet before the exhibits are all properly arranged and labelled.—*Philadelphia Ledger*.

FIG. 1.

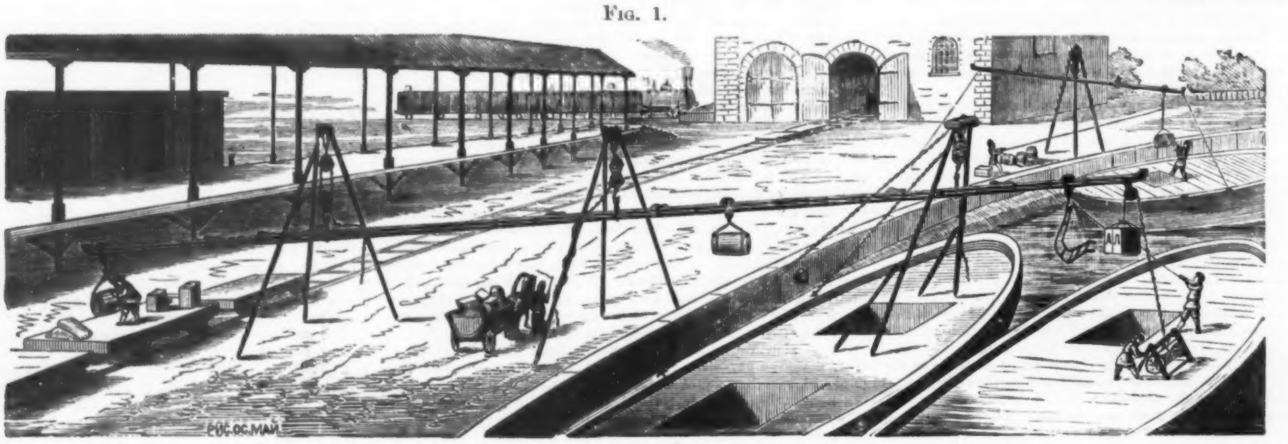


FIG. 2.
A

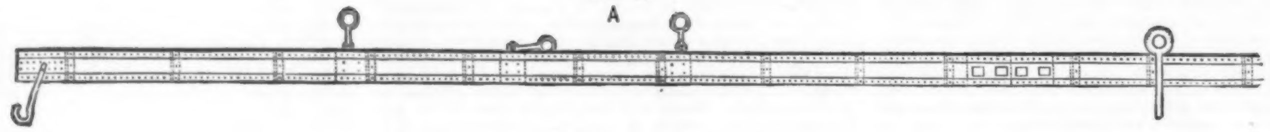


FIG. 3. C

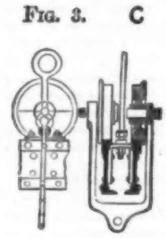


FIG. 5.
B

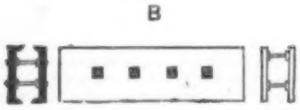
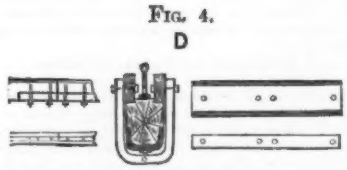


FIG. 4.
D



THE INTERNATIONAL EXHIBITION OF 1876.—THE "GROOSOKAT," OR PORTABLE TRAVELLING CRANE.

THE INTERNATIONAL EXHIBITION OF 1876.

THE RUSSIAN MACHINERY EXHIBIT—A PORTABLE TRAVELLING CRANE.

No. 25.

AMONG the novel and useful things exhibited by Russia, in Machinery Hall, is the "Groosokat," or portable travelling crane, illustrated herewith. This is certainly a very useful invention, and in many respects a novelty. It is designed to form a convenient and cheap means of transshipment of goods and materials in places where the distance is too short for a railroad track, and too great for unloading by means of cranes or similar mechanism, and where goods are usually transported by hand labor, or with horses. The principal localities for the successful use of this invention are wharves, quays, railroad stations, depots, warehouses, manufactories, earthworks, etc., and all places where coal, bricks, sand, wood, grain, cotton, etc., are required to be moved through a comparatively short horizontal distance. It has been in use at Cronstadt by the Artillery Department of the Government since 1872, as well as in many other places in Russia. As a fixed mechanism for the handling of weighty articles, such as is required for large machine establishments, foundries, etc., the overhead travelling crane has to a great extent superseded all former apparatus; and so universal has its use become, that it is found in many places where a very large original outlay has been made for a comparatively temporary purpose—such, for instance, as in the erection of the public buildings in Philadelphia, where one has been erected surrounding the entire square inclosing the buildings—and such is the facility afforded the handling of materials in this way, that the first cost of such temporary structures is found to be economically invested. When the apparatus under consideration is understood to extend to this principle the very desirable property of portability, its value will be apparent. It is essentially a portable overhead travelling crane, supported at intervals upon tripods, or in some cases two-legged supports, as shown in the figures.

Fig. 1 shows the apparatus as used in unloading a vessel, conveying the merchandise to a distance, and depositing it upon a railway truck. Fig. 2 is a side view of the tramway beam, with the suspension eyes and truck. Fig. 3 is a short section in two views of the same, showing the construction of truck and beam. Fig. 4 shows a cheaper form of beam and truck, with the former made of wood, as well as the wheels of the latter. Fig. 5 shows the splice for joining two or more lengths of beam.

As shown, the beam is built up of plate and angle-iron, riveted, and consists of two separate stringers, held together at proper intervals by appropriate cross-webs. At intervals, governed by the strength of the beam and the intended maximum load, are placed pieces in form of a staple of plate-iron, riveted to the inside of the stringers, and to the crown of which the suspension eyes are secured. As shown in the middle cut, Fig. 3, the beam is encompassed by a yoke, the crown of which passes below it, and on the inside of the upper ends of which the wheels of the truck are pivoted, the suspension rods passing between the wheels. In this way there is free passage from end to end for the truck, and the whole may be supported at as many points as may be found necessary.

On the left, Fig. 2, is shown a stationary staple for securing the ends downward, when used with but one support, as seen in the background, Fig. 1. The beams are made in sections of about 28 feet long, as many of which may be jointed together as is necessary for the distance to be travelled, the splice being made by placing the piece (Fig. 5) inside the beam with four square-bodied bolts passing through, as shown at A, Fig. 2.

This apparatus is designed to convey loads up to about 18 cwt. In existing machinery for the hoisting and transporting of materials—aside from the permanent overhead travelling crane—the horizontal distance through which the load may be moved is quite limited, confining this species of machinery to heavy loads, if profitably done; and with such the apparatus in question does not compete for public favor, except where such is used for comparatively light loads. The ordinary swinging crane is vastly more expensive, and very much less efficacious, where loads of a ton or less are to be moved; while this portable crane is far superior in the distance through which loads may be conveyed, is cheaper, and above all quite portable. For the discharge of goods of uniform shape, such as bags, casks, cases, and bales, or of such materials as coal, sand, stone, etc., which readily conform to some uniform kind of receptacle, it is very well adapted, as the chair as shown on the right (Fig. 1), the chime hooks as seen in the centre, or any convenient form of support for the particular load may be attached to the truck yoke.

The tripods are generally about 20 feet high, but can, of course, be made to suit the particular work for, or locality in which it is to be used. The beam is suspended from these by means of a block and falls, in order to adjust the beam to the inclination necessary to convey the load from end to end, which in this machine is done by the action of gravitation. This feature in it will limit its length, as, if constructed for too great distance, the required elevation of the goods at the higher end will be an inconvenient amount. The work of horizontal transport in this case is of course done in the hoisting of the load to the high end of the beam; but it is doubtless economically performed in that way, as generally the same manual labor which is required to raise the load to the required height suffices to guide it to the lower end, or place of deposit, returning the empty truck and sling by the same means.

This instrument is advantageously used for distances up to 100 feet. For the suspension of the beams from the tripods, the Weston differential block is preferably used, as it gives a convenient means of adjusting the heights, and of securing it when adjusted. A very convenient way of using it for unloading vessels is, to connect the support for the load to the truck yoke with a self-checking block and fall, or a differential block of the single sheave kind, and use the same fall for a guy to regulate the descent, and for lowering away at the discharging end of the crane. In this way light loads may be transshipped very rapidly.

This apparatus was patented in the United States in 1870, and is also the subject of patent in Austria, England, Belgium, and Russia. It is the invention of Mr. N. Wonlarlarsky of St. Petersburg, and is in charge of Capt. Alexander Von Der Howen, of the Russian artillery section, in Machinery Hall. It received honorable mention at the Exhibition of Manufactures at St. Petersburg, in 1870, and was awarded a silver model at the Polytechnic Exhibition at Moscow, in 1872.

J. T. H.

IMPROVEMENTS IN GAS ENGINES.

MR. THACKER's arrangement consists, firstly, of a pair of slides working in V-grooves or other suitable guides on the top of the air vessel, which slides are adjusted by screws passing through a fixed nut, by means of which arrangement he is able to vary at will the quantity of atmospheric air admitted at either end of the cylinder. The invention consists, secondly, of an improved discharger or exploder. In Lenoir's exploder there is but one point of discharge for the electric current, which renders the explosion uncertain. Mr. Thacker makes two or more points of discharge, so that if the electric current should fail at one place it is certain to have effect at another, which is a great advantage to the steady working of the engine. He also proposes an improved method of jacketing the cylinder so as to obtain a larger and more complete circulation of water round the same, especially in the immediate vicinity of the ingress and egress ports, and an improved method of making the joint at each end of the cylinder where the cover is joined to the cylinder. Again, in the Lenoir cylinder the openings of the water spaces (or jacket) at the ends of the cylinder render the making of the joints very complicated and almost impracticable. Mr. Thacker's arrangement consists of diverting (by coring) the water circulation, filling up the spaces at the ends of the cylinder, and making the connection between the cylinder and cylinder covers at the top and bottom sides of the cylinder, or in any other part of the external surface which he may find most convenient. He also suggests an improvement in the insulation of the ebonite disk. For this purpose the discharging disk is made of one complete block or slab of ebonite, or other non-conducting material instead of in segments as before, so as to insure more perfect insulation.

USE OF RAIL ENDS IN BLAST-FURNACES.

ACCORDING to Heyrowsky, it has been found at Zeltweg very advantageous to add the crop ends from the rail-mill to the charge on the blast-furnace, and at present, for this reason, the blast-furnace at Zeltweg, which formerly only produced 230 tons of gray Bessemer pig-iron per week, now turns out 270, the increase of the 40 tons in the make corresponding exactly to the quantity of rail ends added to the charge.

LOCOMOTIVE FOR DOM PEDRO RAILWAY, BRAZIL.

THIS locomotive forms one of the exhibits of the Baldwin Locomotive Works at the Centennial.

	Ft.	In.
CYLINDERS:		
Diameter	1	6
Stroke of pistons	2	0
Length of steam ports	1	4
Width " "	0	1¼
" of exhaust ports	0	2¼
Travel of valves	0	5⅜
Outside lap of valves	0	0⅞
Inside " "	0	0 1/32
Exhaust nozzles—double, variable.		
WHEELS:		
Diameter of driving-wheels	4	6
" truck wheels	2	6
Distance between centres of front and rear driving-wheels	15	0
Total wheel-base of locomotive	22	8
" " " and tender	44	3
Diameter of driving-axle journals	0	7
Length " "	0	8
Diameter of main crank-pin bearing	0	4½
Length " "	0	4¼
BOILER:		
Outside diameter of smallest ring of boiler	4	8
Thickness of boiler-plates (iron)	0	0½
Number of tubes	159	
Length "	11	2¾
Outside diameter of tubes	0	2
Length of fire-box inside	5	5
Width " "	2	11⅝
Depth " "	5	3¼
Thickness of fire-box plates (copper), side, back, and front sheets	0	0½
Thickness of flue-sheet	0	0⅝
" crown-sheet (steel)	0	0⅜
Square feet of grate-surface	16	
" heating surface in fire-box	103	
" " " tubes	937	
Total square feet of heating surface	1040	
TENDER:		
Number of wheels	8	
Diameter "	2	4
" tender-axle journals	0	3¼
Length " "	0	7
Capacity of tank	2000 gallons.	

	Lbs.
WEIGHT:	
Weight of engine in working order	80,000
" " on driving-wheels	68,000
" of tender, empty	20,000

MATERIALS:
Boiler, J. L. Bailey & Co.'s "Pine" Iron; *Fire-box*, Hendricks Brother's Copper; *Tires*, Standard Steel Works' Crucible Steel; *Engine, Truck, and Tender Wheels*, Ramapo Wheel and Foundry Company's Double Plate Chilled Wheels; *Flues*, W. C. Allison & Sons' Lap-Welded Charcoal Iron Boiler Tubes; *Injector*, William Sellers & Co.; *Steam-Gauge*, Buffalo Steam-Gauge and Lantern Company; *Brass and Copper Piping*, Benedict & Burnham Manufacturing Company; *Staybolts and Tank Iron*, Catasauqua Manufacturing Company; *Jacket Iron*, W. D. Wood & Co.'s Patent Planished Sheet-Iron; *Head-Light*, Philadelphia Railroad Lamp Works.

THE SOUTHERN PACIFIC RAILROAD.

A NOTABLE RAILROAD CONNECTION.

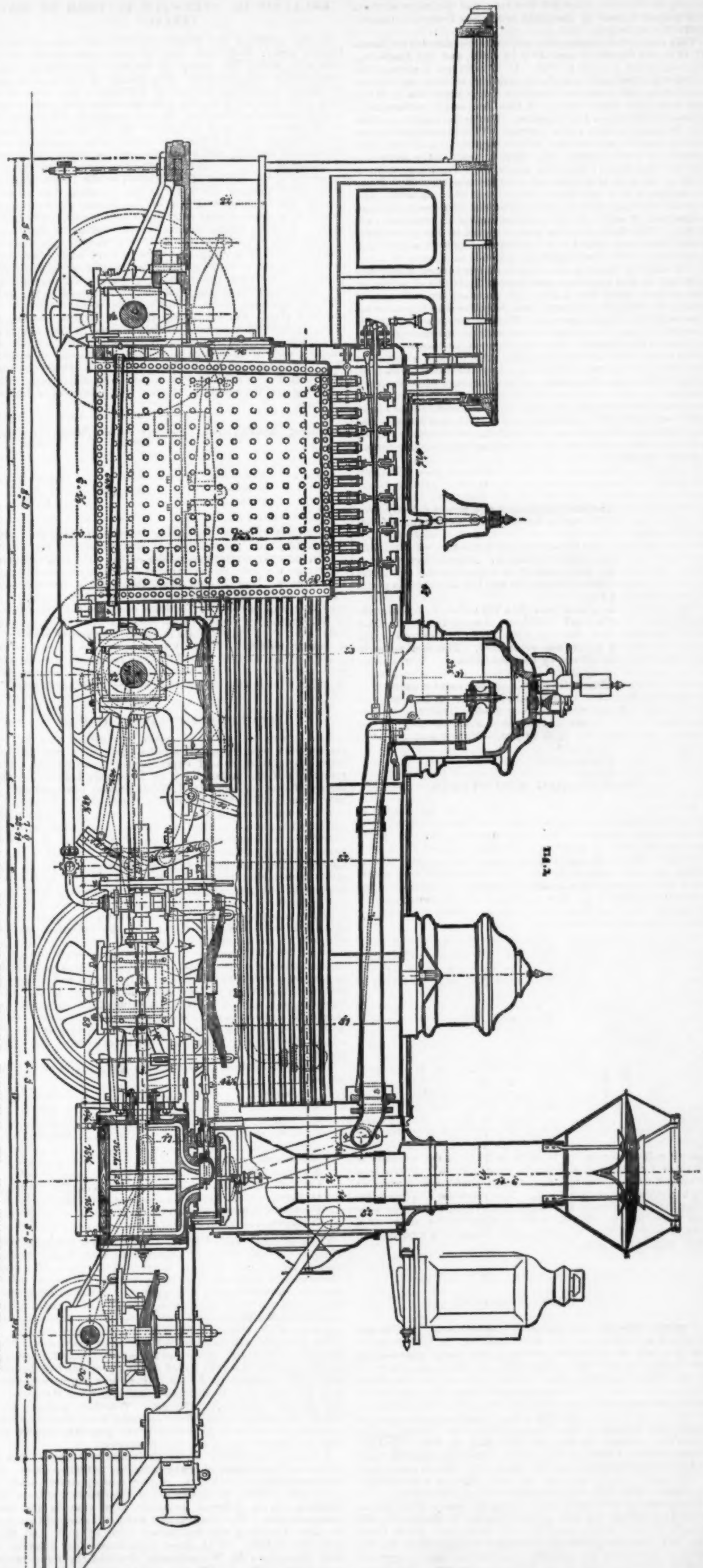
THE event of driving the last spike in the railroad connection between San Francisco and Los Angeles, which occurred on September 5th, 1876, was one of great importance, indicating as it does the gradual opening up of Southern California, Arizona, etc., and bringing them into more direct communication. The road passes through the San Joaquin valley, from Lathrop in the north (where the line branches from the Central Pacific), to Tehichipa, a distance of 300 miles, on almost a level. The work of track-laying was comparatively inexpensive, with bridges crossing the Stanislaus, Tuolumne, Merced, Fresno and Kern Rivers, and other streams flowing from the mountains to the San Joaquin. The San Joaquin Valley Railroad, which comprises this section of the road, intersects the counties of Stanislaus, San Joaquin, Merced, Fresno, Kern and Tulare, and all the products of Tuolumne and Mariposa counties will find their way to market on this great highway.

The only natural passes across the barrier separating Los Angeles from San Francisco are the Tehichipa and Tejon passes, the former of which was chosen by the railroad engineers as the easier through which to run their track, and from there it debouches into the Mohave desert. These were not the only obstructions to be overcome, and the San Fernando tunnel, the longest on this side of the continent, had to be bored, and the work was performed with more than ordinary expedition.

San Francisco is now placed in communication by rail with Los Angeles, San Bernardino, Santa Monica, Wilmington, Anaheim and Santa Ana. Los Angeles is now the centre of an extensive railroad system, branches extending to Santa Monica, Wilmington and Anaheim, besides the main trunk of the Southern Pacific Railroad, which runs through it. The branches extending to Wilmington and Anaheim are owned and controlled by the Southern Pacific Railroad Company; that to Santa Monica is the nucleus of the Los Angeles and Independence Railroad. All that remains of the Southern Pacific Railroad to be built is from Indian Wells to the Colorado River, at or near Fort Yuma.

The engineering difficulties in building this road were very great, and those encountered in ascending the Tehichipa canyon surpass any thing encountered on an equal distance in the Sierra Nevada. Every artifice had to be employed to enable the engine to climb the steep grade, and within 19 miles there are 17 tunnels in ascending the Tehichipa. A few statistics regarding the length and size of these tunnels can not prove uninteresting. Tunnel No. 1 is 245 8-10 feet long; No. 2, 232 2-10 feet; No. 3, 707 7-10 feet; No. 4, 257 feet; No. 5, 1156 3-10 feet; No. 6, 303 7-10 feet; No. 7, 532 7 10 feet; No. 8, 690 feet; No. 9, 426 2-10 feet; No. 10, 406.6 feet; No. 11, 158.8 feet; No. 12, 756.3 feet; No. 13, 513.8 feet; No. 14, 512.7 feet; No. 15, 360.7 feet; No. 16, 262.5 feet; No. 17, 360.9 feet; making a total of 7683.9 feet. Nearly all these tunnels are heavily timbered with stanch 11 x 14 inch redwood timbers. At the bottom they are 14 feet in the clear, or 16½ feet in excavation. They are 22 feet in height, and the shoulders, at the springing of the arch, are 18 feet 4 inches. In the Soledad canyon there are two more tunnels, numbered

THE INTERNATIONAL EXHIBITION OF 1876.—LOCOMOTIVE FOR THE DOM PEDRO II. RAILWAY, BRAZIL.



18 and 19, the first being 264 feet long, and the latter 332 feet. The longest tunnel on the coast is the San Fernando tunnel, 6966½ feet in length.

This triumph of engineering skill was commenced on March 27, 1875, the headings met July 14, 1876, and the timbering was completed August 9, 1876. It is built on a slope of 37 feet to the mile, and is perfectly straight, so that one can see through it. It is not cut through a single mountain, as is the case with most undertakings of this kind, but runs through a succession of ridges and canyons. The entire length is 6966 feet, or nearly a mile and a quarter. This is exclusive of the heavily-graded approaches, which aggregate half or three quarters of a mile more. The deepest point in the tunnel is 600 feet below the top of the mountain. The excavation is made in the form of a trapezoid, only that the top, which forms the longest side of the figure, is surmounted by an arch. The width of the bottom is 14 feet, the height of sides to the commencement of each, 16 feet, and the height to centre of arch 21 feet. The sides and top are protected by heavy timbers, braced, fitted and spiked into the aperture as soon as the earth is removed. The south approach ascends at a grade of 2 feet in 100, until it reaches the mouth of the tunnel, where the road-bed strikes a uniform gradient of 71-100ths of a foot in 100, rising toward the north. At the northern extremity it reaches its highest point, and then descends with the same incline as the southern approach. Work was commenced simultaneously at both ends, and at three intermediate points on the line of the tunnel. From these points inclines were sunk to the level of the road bed to further the work of excavation and provide ventilating facilities when the tunnel was completed. The tunnelling was originally started some distance from the present face, but the overlying earth caved in so badly that it was found necessary to make excavations about sixty feet deep before sufficiently solid earth was found. Another obstacle which presented itself was an excessive flow of water, rendering the work of excavating not only dangerous but very expensive.

Tunnel 9 is at the famous loop of Tehichipa pass. This loop completely encircles a mound, and by so doing gains a difference in elevation of 77 feet 46 inches. Emerging from tunnel 9, the train winds around the mound and passes directly over the tunnel at right angles, having made a curvature of 300 feet 52 inches. The length of the loop is 3794 feet. Pictured on the map, this loop looks like a coil thrown carelessly in a rope; it is a veritable corkscrew. It is claimed to be a novel and original achievement in engineering. The total length of tunnels between Caliente and Los Angeles, as given above, is 15,246.4 feet.

The road has been built to within 100 miles of the Colorado River, which it will reach before the close of the year. The whole distance from here to Fort Yuma by the road is 715 miles, over 600 of which are completed. The last spike in the connection was driven by Charles Crocker. It was made of Los Angeles County gold. Appropriate ceremonies, participated in by the railroad directors and prominent citizens from Los Angeles and San Francisco, were held. A banquet was given, toasts offered, and speeches made. Trains leave San Francisco daily for Los Angeles at 4 P.M., arriving at Los Angeles the next day at 3.30 P.M.—*Mining and Scientific Press.*

ENGINEERING STRUCTURES.

Monolithic Aqueduct.—The aqueduct from La Vanne to Paris, 135 miles long, is nearly entirely of *beton Coignet.* The Fontainebleau section of thirty-seven miles, over dry quicksand, is composed of a series of arches, some of them fifty feet high. Eight or ten bridges, of span from seventy-five to ninety feet, are also of *beton.* For foundation and gravel walls, the composition is: sand 2½, gravel 2½, hydraulic lime 1, Portland cement ⅛. For pillars, abutments, etc.: sand 4, hydraulic lime 1. The other portions: sand 4, hydraulic lime 1, Portland cement ⅛ to ¼.

Underground Pumping Engines.—At the Society of Engineers' meeting, in the Society's Hall, Westminster Chambers (Mr. V. Pendred, president, in the chair), a paper by Mr. Henry Davey, "On the Underground Pumping Machinery at the Erin Colliery, Westphalia," was read. The paper described what is probably the largest example of underground pumping engines extant. The system, which was originated by the author, may be thus briefly described. In the mine (which is 1200 feet deep) 920 feet from the surface is placed a pair of compound differential pumping engines, capable of raising 1400 gallons per minute to the surface, at the same time supplying power through the medium of the rising column to two differential hydraulic pumping engines placed at bottom of the mine, and employed in lifting 1000 gallons per minute to the main engines. Steam is carried down to the main engines from the surface at a pressure of 70 lbs. per square inch. After passing through the engines it is condensed, and a vacuum of from 24 to 26 inches of mercury is obtained by means of a separate condenser, which produces at once a vacuum on the engine, and enables it to start to work against the full column. The methods employed for actuating the valves in the steam and hydraulic engines were also fully shown. In the latter case the valves are worked without any metallic connections by means of a modification of the differential gear.

A NEW FRENCH IRON-CLAD.

The new French iron-clad, the "Redoubtable," which was launched at l'Orient, on the west coast, on the 18th September last, will be the most powerful war vessel possessed by the Republic. It was commenced in 1873, on plans by M. De Bussy, in which the eminent Director of the Naval Construction Yard of l'Orient embodied what he conceived to be the best features of the Blaunel fleet. This latest addition to the ocean defence of France is a fourth larger than the vessel best known of the French fleet, the "Ocean." One prominent feature of the new iron-clad is, that it is built almost wholly of steel—a fact which shows the progress made in French workmanship of late years. All the exposed parts of the vessel are plates, and in front there is a formidable iron spur. The deck and magazines are all bomb-proof. The "Redoubtable" will carry eight pieces of heavy artillery, arranged according to a new method, which, it is believed, will permit of their being used in every direction. Great attention has been bestowed on the speed of the vessel; its machinery has been manufactured after the most approved models at Creuzot, and is of 6000 horse-power. The helm, capstan, and pumps of the "Redoubtable" will be set in motion by steam machinery, which embraces all the latest inventions, and unites the greatest power with the finest delicacy of control.

RELATION OF STRENGTH TO FORM OF MATERIALS.

In the rooms of the Master Car-Builders' Association on Liberty street, New-York, may be seen some specimens of rods with which Mr. Garey, of the New-York Central road, has recently experimented. The results of the experiments are rather disturbing to some of the ideas which some of us have held, and will compel a general overhauling and correction of established theories. In the numerous discussions of the subject of the dead weight of cars, it has several times been proposed that the round rods used in the construction of cars should be thickened up on the ends on which the thread of the screw is cut, so that the effective diameter of the rod measured at the bottom of the thread would be the same as at the other parts of the rod. It was assumed that the rod, having less transverse section at the bottom of the thread, would be weakest at that point and would consequently break there. Nothing seems plainer, more obvious or more conclusive than this. The results of Mr. Garey's experiments, however, show how dangerous it is to draw such inferences, or rather to act on them without demonstrating them by experiment. He took three rods of ¾, ⅝ and ½ in. diameter respectively, and 3 feet long, and then cut a thread in the ends without upsetting them. The threads were of the U. S. standard sizes. On subjecting them to strains, instead of breaking through the screw, as they seemed in duty bound to do, each one of them broke near the centre. At the point of fracture, each of them was very much contracted in section, that is, was drawn down by the tension, as is always the case when soft iron is subjected to severe tensional strain. The following are the breaking strains and diameters of broken sections:

Diameter of rod.	Breaking strain.	Diameter at point of fracture.	Stretch of rod when broken.
¾ in.	43,000 lbs.	9-16 in.	2¼ in.
⅝ "	33,000 "	7-16 "	2⅜ "
½ "	24,000 "	⅜ "	2 15-16 in.

These experiments present an interesting problem, both theoretically and practically. It was stated by Mr. C. A. Smith, formerly master car-builder on the Erie Railway, that in practice the rods on cars almost invariably break through the threads. Now if this is so, the problem becomes still more intricate, and its theory more difficult to explain. If the experience of other car-builders confirms the observation of Mr. Smith, the question then presents itself, why do such rods break at one place while in use on cars and at another in a testing machine. If, as we suspect, this is due to the quality of the material of which they are made, then it indicates anew the importance of testing carefully all the iron which is used so as to know its quality.—*Railroad Gazette.*

HEAT-CONDUCTION IN GASES.

The power of different gases to conduct heat has in recent years been frequently studied, both in the way of theoretical calculation and of experimental measurement. The researches of M. Stefan have an important bearing on the theory of gases. Recently M. Winkelmann has published a new investigation of the subject in *Poppendorf's Annalen.*

For measurement of the heat-conduction M. Winkelmann employed the same method as has been employed by other observers: he measured the velocity of cooling of a thermometric body within a vessel filled with the gas to be examined. The difficulty of these experiments lies in the circumstance that the cooling is caused not only by the conduction of the gas which surrounds the cooling body, but that also the currents of the gas and, above all, radiation play an important part. M. Winkelmann considered it his chief task to eliminate the currents of the radiation; and he effected this in one case by altering the pressure of the gas between 760 and 1 mm. (with decreasing pressure the action of gas currents becomes less). Secondly, he employed various apparatuses in which the cooling body within was always of the same dimensions and the same material, while the outer envelope was altered in size; the value of the radiation was then in all apparatuses the same, while the conduction varied with the size of the outer vessel, and so furnished data by means of which the radiation could be calculated and eliminated.

The results of these measurements are given in the following table:

Gases.	Conductivity.
Air	0.0000525
Hydrogen	0.0003325
Carbonic acid	0.0000317
Ethylene	414
Marsh gas	647
Nitric oxide	460
Carbonic oxide	510
Oxygen	563
Protoxide of nitrogen	363
Nitrogen	524

The numbers obtained for air and hydrogen, the gases with which the fullest series of experiments were made, further showed that in air, down to a pressure of 1 mm., the heat-conduction is *independent* of the pressure; hydrogen, on the contrary, showed a quite divergent and hitherto unexplained behavior in reference to pressure, in that the changes of the currents with different pressures by no means afford an explanation of the observed differences in velocity of cooling.

For example, whereas with a lowering of the pressure from 750 mm. to 91.4 mm., there was a change of only 1.4 per cent in the value for the velocity of cooling; on further diminution of the pressure to 4.7 mm., there was a further decrease of 11 per cent, and this decrease continued when the pressure was further lowered to 1.92 mm. Whether, perhaps, accidental circumstances may have operated here, or whether the phenomenon is due to properties of the gas, can only be decided by further and more exact researches.

A second task which M. Winkelmann set himself was to determine the relation of heat-conduction to temperature. In this investigation he had to employ new apparatus made of glass, and to effect the separation of the conduction from the radiation on a different principle from that in the first measurements. The observations were so arranged that first the time of cooling was determined from 18° to 8°, and then from 118° to 108°. With three apparatuses very different in their dimensions, M. Winkelmann obtained the temperature coefficients 1.3661, 1.3429, and 1.3644, referring to the temperatures 7.4° to 7.6°, and 107.7° to 109°—that is to say, if the heat-conduction at the lower temperature be put equal to 1, then at the higher temperature it has the value just given.

Besides the two gases, air and hydrogen, carbonic acid was examined. If the latter changes its heat-conduction with temperature in the same way as air and hydrogen, we should, by combination of the values of hydrogen and carbonic acid, obtain the same relative numbers as those given relating to hydrogen and air. The values so obtained, however, are altogether smaller, whence it appears that the conduction of carbonic acid is not dependent on temperature in quite the same way as that of hydrogen, but increases more quickly with the temperature.

PURIFICATION OF METALS BY FILTRATION.

Professor Lampadius, of Freiberg, concluded that at a certain low temperature of fusion, the metallic impurities present in the more easily fusible metals would separate, partially as such, and partially as definite, crystalline compounds, and float in the fused mass, from which they could be removed by filtration. Experiments by him in this direction were so far successful that the expected definite compounds were found upon the filter, but the metallic filtrate was still very impure. The filter was made of quartz, sand, slag, etc., which was not wet by the molten metal. Carter, however, according to a communication by him, in trying to adapt this principle to the purification of Bohemian tin, on a commercial scale, sought for material for a filter, which would be wet by the metal to be purified, without being dissolved in it. Iron, with its comparatively high temperature of fusion, and its adhesion for tin, as manifested in the tinning of iron, was employed for the filter. Five hundred strips of tinned iron, as thin as paper, about 0.6 of an inch long, and one fourth as broad, were packed tightly in a square iron frame, by the aid of wedges, and the frame was then luted into a suitable opening in the bottom of a graphite crucible. The tin melted in a second crucible was allowed to cool until the separation of fine crystals on the surface was noticed, and the thickening metallic mass was then poured into the filtering crucible, when the still fluid, pure metal passed through, and a pasty magma was left, in which iron, arsenic, and copper, concentrated to a great degree, were found combined with tin, while the filtered tin proved to be almost chemically pure. Fifty hundredweight were purified in the crucible described. Other forms, and other materials for filters, are suggested, and other possible applications of the method, as in the separation of silver from lead containing the former metal.

BOOT-CLEANING MACHINES.

Boot-cleaning machines have occupied the attention of inventive mechanicians for some years, but up to the present time the only machines that have been invented for the purpose are rather apparatus to assist the operator or boot cleaner than real boot-cleaning machines. Two machines have, however, recently been patented which promise to realize the sanguine anticipations of their inventors, and to delight hotel-keepers and others by the promised saving in labor. One of these inventors is Mr. Southall, of Leeds, who has designed a machine about the size of a small lathe or an ordinary sewing-machine, and has contrived to impart to the brush the backward and forward movement which seems to be absolutely necessary to produce a polish on leather. A horizontal sliding shaft runs in bearings on the frame of the machine, a worm-wheel in one of the bearings acting as "feed" for revolving the boot, which is held firmly on an expanding last. A rocking-bar carries an arm to which the brush is attached, and is so fitted that the brush lever can rise or fall according to the inequalities of the surface of the boot. The driving shaft carries a worm for turning the feed, a fly-wheel, a crank, and cams for giving the brush the backward and forward motion. The boot being secured on the last, and the brush adjusted to the proper distance, an ordinary crank-handle is turned, and the polishing proceeds to a satisfactory termination. It would appear, however, that this machine only polishes the boot. What is wanted is a machine into which a dirty and probably muddy boot can be placed and cleaned and polished merely by turning a handle or by setting the machine in motion, for steam-power would doubtless be utilized when possible. Such a machine is promised by the specification of a patent obtained by Mr. W. H. Kent, of Blackfriars road, for an invention which relates to improvements in machinery or apparatus for cleaning and polishing boots and shoes, whereby the dirt is cleaned off, the blacking put on, and the boots or shoes polished at one operation. For this purpose, a pair (or any number of pairs) of brushes have a straight reciprocal motion imparted to them, also a side action, allowing the brushes to take any angle to suit the shape of the boot or shoe to be cleaned. There is also an arrangement for contracting or expanding the distance between the pairs of brushes, and a revolving platform on which the boot or shoe is fastened, together with an arrangement for conveying the necessary quantity of blacking to the boot or shoe. A suitable frame of wood or metal is arranged with bearings to carry a shaft, having two or more cranks with rods attached, extending to blocks having the brushes hinged to them, with springs on the back of the brushes, arranged to keep a continuous pressure in whatever positions the brushes are in. The slides carrying the blocks in which the brushes are attached work on rods, on which they are caused to slide by means of a cam arranged at the lower part of the machine, levers being attached which expand or contract the space between the brushes. The boot or shoe is put upon a suitable last, which rests upon a platform running upon centres—the lower centre under the platform; the upper centre on the top of the last being kept in its place by suitable springs or levers—the platform and last revolving on their centres driven by cog-wheels connected to main shaft. For conveying the blacking to the boot or shoe, a suitably shaped bottle of blacking is fixed to the bottom of the machine, in the centre, between and just below the brushes. Inserted in the bottle is a round piece of wood of suitable diameter, and long enough to reach from bottom of bottle to the top of the case in which the machine is inclosed, and working through suitable bearings, with a knob attached on top. The lower part of the piece of wood that goes into the blacking has a coarse screw-thread cut in it to hold the blacking when withdrawn from the bottle. When the blacking is to be put on the boot the knob is pulled up, the brushes then come in contact with the end of the piece of wood, and a few turns of the handle of the machine thoroughly blackens the boot, the knob falling to its place on withdrawing the hand. A few more turns of the machine, and the boot is polished. The boot or shoe to be cleaned, and all the machinery being perfectly inclosed, there is no escape of dirt, the three operations—namely, brushing off the dirt, putting on the blacking, and polishing—being all completed in a few revolutions of the machine. It will be noticed that in this machine it is necessary to have human labor to assist the machine in putting on the blacking.—*English Mechanic.*

HUMMING-BIRD WINGS.

By Dr. ELLIOT COUES, U. S. A.

THE wings are remarkable in several aspects. In general they are thin, sharp, and pointed, with long, stiff, curved primaries, rapidly graduated, and short secondaries, resulting in the shape especially to be called falcate. They have but six remiges, in addition to the ten primaries. The upper arm-bone is extraordinarily short: perhaps representing the extreme of this condition among birds. The breast-bone is very large, and has an enormous keel: this is in relation to the immensely developed pectoral muscles that move the wing. The whole conformation illustrates perfectly a well-known law, yet one not often mentioned, respecting the movements of the wing of a bird—namely, that the nearer to the body the longest quill feather is, the more rapidly is the body moved. We will assume, for example, what is very near the truth, that a humming-bird and an albatross have about the same relative length of wing in the "hand" or pinion portion that bears the ten primaries, and the same relative length of these quills. In the albatross this portion of the wing is widely separated from the body by the length of the humerus and fore-arm; in the former, the reverse extreme exists; and we see the result in the long, measured sweep of the ocean-bird's wing and the rapid strokes of the others. This is in strict accordance with a mechanical law respecting the ratio between time of motion and distance traversed. Given, say, a hummer's wing two inches from flexure to tip of first primary, and one inch from flexure to shoulder-joint: this would make the point of the wing describe an arc of a circle with a radius of three inches; and a certain amount of muscular contraction effects this in a certain time. Now, lengthen fore-arm and upper-arm till they are each about two inches long, which would be something like the relative lengths in an albatross's wing: this would make the point of the wing move in an arc of a circle with a radius of ten inches. Now, the muscular force remaining the same, it is evident that the point of the wing could not move through this much larger arc in the same time—that is, the wing-strokes would be necessarily slower. It is interesting to observe how, in some other birds, a similar result is brought about by different means. In a partridge, for instance, without special shortening of upper-arm or fore-arm, the longest quill-feather is brought nearer the body by the roundness of the wing—that is, the successive shortening of several outer primaries; and this bird, as is well-known, makes correspondingly more rapid wing-beats, and vigorous, whirring flight. In the humming-bird the quickness of the wing-vibration reaches the maximum; so rapid is it that the eye can not follow the strokes, but merely perceives a film on each side of the body. The flight of the bird is also the most rapid; frequently the eye can not follow the bird itself. It is almost needless to add that the peculiar sound, from which the family takes its English name, is not vocal, but produced by the wings, just as it is in the case of so many insects.

THE DAWN-ANIMAL.

CHIEFLY through the labors of the late Sir W. Logan, in conducting the Geological Survey of Canada, we have become acquainted with an enormous series of deposits older by far than any stratified rocks previously recorded. These ancient and altered rocks, which are typically developed in the Laurentide Hills to the north of the St. Lawrence Valley, and are hence fitly termed "Laurentian" rocks, form a series, at least 30,000 feet in thickness, divisible into an Upper and a Lower group, and consisting for the most part of gneiss and limestone, associated with vast deposits of iron-ore, and in the Upper series with thick beds of basic felspar. For many years these rocks had been searched in vain for traces of any organic remains, and hence they were classed with those strata which were somewhat rashly termed "azoic." Yet there were not wanting reasons, partly chemical and partly biological, for conjecturing that the formation of some of these deposits was connected more or less directly with organic agencies. At length the day came for verifying these conjectures. In 1858 some specimens obtained from the Lower Laurentian limestones were suspected by Sir W. Logan to owe to an organic origin the obscure structure which they presented; and Dr. Dawson, on examining them under the microscope, not only confirmed this suspicion, but pointed out their relations to the Foraminifera, and at the same time suggested the now well-known name of *Eozoon*, or the "Dawn animal." When specimens of this supposed fossil were submitted in 1865 to Dr. Carpenter and Prof. Rupert Jones, the highest authorities on the Foraminifera in this country, Dr. Dawson's conclusions were verified and strengthened, and henceforth Eozoon was ready to take its place as the oldest known fossil.

Although Eozoon may appear to be an insignificant object, the importance of its discovery in extending our knowledge of the range of life may be inferred from Sir W. Logan's remark that, in comparison with the age of this fossil, "the appearance of the so-called Primordial Fauna may be considered a comparatively modern event."

Dr. Dawson admits that in suggesting the name Eozoon he had "no intention to affirm that there may not have been precursors of the dawn-animal." The history of the discovery of such a body in rocks which so long seemed hopelessly barren of fossils should stimulate further search in these ancient deposits, in the hope that haply they may yield some other traces of Laurentian life, and thus reveal to us the contemporaries, if not the forerunners, of Eozoon.—F. W. RUDLER, in *The Academy*.

THE DEPTFORD VICTUALLING YARD.

THE third of the intersessional visits of the Society of Engineers for the present year was lately made, when the Members and Associates visited the Royal Victoria Victualling Yard at Deptford. There were present, among others, Mr. R. P. Spice, one of the vice-presidents; Mr. C. Barnard, Mr. Jabez Church, Mr. Copland, Mr. Schonheyder, Mr. Addenbrooke, and Mr. P. F. Nursey, Secretary. In the absence of the Superintendent, Mr. Grant, the visitors were received by his deputy, Mr. McKain, by whom, with the engineer to the yard, Mr. Storrar, they were courteously conducted over the establishment. They first visited the bakery, where they saw the flour and water mixed by machinery for the biscuits; the dough passed first under the action of grooved, and afterwards under that of plain rollers, driven by steam power. It was then passed on to cutting tables, where the biscuits were stamped from the sheet of dough and passed into the ovens. From the ovens they saw the biscuits conveyed to the drying floor above, which is heated by the waste heat from the open furnaces, and where they are subjected to a maximum temperature of 140 deg. Fahrenheit for three days. After that they are removed to the stores and packed in bags for use in the navy, and in tin-lined boxes for export to distant naval stations. The productive power of the bakery is 44,000 lbs., or nearly 20 tons, per day in full work. From the bakery the visitors were conducted over the flour mills, when the successive operations of producing flour from the grain were witnessed and the engines inspected. From the flour-mill to the oat-mill was a short step, and there the visitors saw the oats shelled and ground into oatmeal. The chocolate the mustard and the pepper mills were then visited in succession, the chocolate mill not being at work, as chocolate is only made in cold weather. The stores for the naval station, were then visited, as also was the "color" department, where a series of Thomas's sewing machines, driven by steam power, and attended by women, were producing every kind of flag. In this department was a testing machine for sail-cloth, which is tested both for weft and warp. The breaking strain for the weft of No. 1 canvas, cut into strips of an inch wide, is 430 lbs. Samples tested before the visitors stood 550 lbs. before giving way. The test for the warp is 340 lbs., and samples stood 385 lbs. before breaking. The bunting for the flags is also tested, the test being 100 lbs. on the 6 in. wide strip. Samples tried stood 120 lbs. The sail-making department was next inspected, where steam-driven sewing machines of large size were at work, tended by men. The visitors were next conducted over the cask-making machinery department, where they saw the staves of the barrels steamed, bent, joined, and put together, and the heads formed and fitted, the majority of the operations being satisfactorily performed by Greenwood and Batley's machinery. The cooperage, where hand-made casks are still produced, was next visited, and then the general stores, which are of very great extent. The visitors were finally conducted over the rum stores. There the rum is received from the West Indies forty per cent above proof, and is reduced by the addition of water to four per cent under proof, and is vatted. There are over thirty vats of varying capacities, the largest being capable of holding 32,817 gallons of rum. The various processes were inspected with much interest, and the courtesy and attention of the officials throughout were most marked. The machinery, with the exception of the chocolate mills, is not of the most modern type, but is doing its work well, and is throughout the yard well kept. After a pleasant and instructive visit, some of the members and their friends dined together at the City Terminus Hotel.

HEROIC FARMING.

THE mode of culture, and the liberal manuring practised by market gardeners, can not of course be generally adopted by those who cultivate large areas of land. But I have always noticed that those farmers whose methods approach nearest to the standard of the garden are the ones who obtain, as a rule, the largest yields and the highest rate of profit. It is true enough that to invest yearly in manure at the rate of 50 to 80 tons per acre, requires more faith and courage, as well as more money, than the average farmer commands. Yet it is mainly in this intensive mode of culture that the market gardener finds his best remuneration. The man who cultivates half a dozen acres must get larger returns from each than those who cultivate from fifty to five hundred. To get seventy tons of cabbages from an acre, and other products in a similar ratio, the gardener can well afford to invest liberally in plant-food and other expenses of culture. If he knows, or can nearly determine, the value of each intended crop, he can generally calculate how much it will be safe to pay out in order to obtain it; and having made the calculation, he does not hesitate to make the investment.

Now, there is clearly no reason why the same general rule is not equally sound for the farmer. His business is subject to the same natural laws, and his crops are augmented by the same process. When the Hon. Henry Lane, of Vermont, by adding a few dollars to the cost of his beet crop, brought the yield up to 44 tons per acre, and the cost down to 6 or 7 cents per bushel, though he achieved no miracle, he showed that intensive culture is profitable for the farm as well as for the garden.

The grand fact to be considered is this: In all cases where manure is abundantly supplied, and the tillage is thorough and deep, the soil responds in a corresponding degree, and becomes, in the hands of a skilful cultivator, simply a machine for converting chemical elements into food; and whether a man cultivates ten acres or ten hundred, the more plant food he supplies of the right kind (other conditions being equal), the larger will be the result, the lower the cost, and the higher the rate of profit.

The last few dollars added to the cost of the crop is nearly always the secret of the extra profit, and sometimes makes the whole difference between profit and loss. All practical farmers profess to understand this, yet few of them have proved the courage of their opinions by reducing it to practice. And here is just the point where men of timid and conservative policy halt and hesitate, while the clear-headed, heroic farmer fearlessly meets the expense and wins the prize.

There is, in fact, scarcely a crop raised on the farm that might not be materially increased with but slight additional cost, provided the owner could determine in each case the additional outlay needed, and the right place to put it. As this question is often easily solved, and not always as difficult as it seems, it challenges the attention of farmers, and well deserves further discussion.—CONRAD WILSON, in *Country Gentleman*.

SOFT-SOAPING THE SPIRITS.

AT a table-turning entertainment given recently at Leigh, Lancashire, after the manifestations had duly set in, a Mr. Evans, a surgeon, obtained permission to apply a somewhat novel test. He covered the tops of the tables and the fingers of the sitters with a coating of soft soap, after which every attempt to persuade the table to spin proved ineffectual. This result is said to have spread considerable dismay in the ranks of the spiritualists who were present.

NEW DRY-DOCKING SYSTEM.

By CLARK & STANDFIELD, London.

IN our SUPPLEMENT No. 25, page 392, we gave drawings in section and elevation of this new style of dry-docking. We now present a view in perspective, which further illustrates the actual working of the improvement. A dock on this plan is now in progress of construction at Milwall, Eng., for the Russian Government.

This dock is not only capable of raising and lowering vessels of any size with facility, but it also further deposits them, in any number required, high and dry upon fixed timber stages, where they can be cleaned, painted, repaired, and lengthened at leisure.

Vessels of any size or form can also be most conveniently and economically built on an even keel on these stages, and when completed can be lowered into the water without strain and if required, can be again lifted on to the staging almost without cost.

The staging on which the vessels are deposited consists of a number of parallel rows of piles driven into the ground in a direction transverse to the length of the vessel, the space between each row of piles is sufficiently clear and open, and is of sufficient width to receive the projecting pontoons of the dock, which carry the vessel at a height somewhat above the top of the piles. The dock itself consists of a number of pontoons, which may be either of tubular or rectangular form. These pontoons are arranged parallel to each other, at suitable distances apart, and are fixed at one end to a longitudinal frame or floating girder, and are free at the other end, so that the whole structure in plan resembles a comb or the fingers of the hand, the pontoons corresponding to the teeth or fingers. The dock is sunk beneath the vessel, and the water being pumped out (or forced out by compressed air) it rises and lifts the vessel upon it out of the water; in this state it is floated to the staging, the pontoons entering into the opening between the stages, and the vessel, itself being clear above them. A little water is now admitted into the pontoons, which causes them to sink until the vessel rests upon the stages, and the pontoons are withdrawn. In order to steady the vessel upon the pontoons, and also when resting upon the stages, it is raised upon a longitudinal frame or cradle which is sunk with the pontoon, and which carries the necessary bilge blocks, etc., for steadying the ship. It is obvious that with one dock any number of vessels may be thus successfully raised and deposited on stages, and may be again removed and lowered into the water at pleasure. The dock, as before stated, consists of a number of parallel pontoons, separated by intervals, and all united at one end to a hollow floating girder. This girder also carries a row of hollow vertical cylinders fixed upon it, and these are of such a length that when the pontoons are submerged beneath the vessel, the tops of the cylinders are at a convenient height above water. A platform is carried along the top of all the cylinders for convenience of access. The end section of the dock therefore resembles the letter L, the pontoons forming the horizontal line, and the tubes the vertical stroke. It is moreover obvious that such a form, however stable it may be when above water, would be perfectly unstable when submerged, and it therefore requires some extraneous addition to give it stability during submersion. This is effected by an arrangement of parallel bars attached to a floating caisson at the back of the dock, and so arranged that while the dock is quite free to ascend or descend in the water, it can not move out of its horizontal position without capsizing the caisson, which is made sufficiently wide and heavy to render the movement impossible.

The pontoons have in themselves sufficient buoyancy to support the entire weight of the vessel and cradle without any assistance from the floating girder or the vertical tubes, which are not made use of as a lifting power at all. The vertical tubes are in fact carried by the girder, and their only office is to *steady* the dock while it is being raised or submerged. After the vessel is raised the vertical tubes are out of use, the whole weight being supported by the pontoons alone. From the great width of the pontoons and the floating girder, the whole structure when afloat is eight or ten times more stable than the ship itself.

Each of the pontoons is divided into six independent watertight compartments, irrespective of the compartments in the box, girder, and in the vertical tubes, and as the pontoons vary in number, from fifteen to thirty, the whole dock is divided into from one to two hundred separate watertight compartments, each connected with the pumps by independent pipes and valves. A great many of these compartments are hermetically sealed up, and their number and position is such that the dock can not sink even if all the valves be purposely left open. It has in fact a tendency to float well above water, and is only forced down to a sufficient depth to receive a vessel by admitting water into the vertical side. The whole system of compartments is divided generally into four groups corresponding to the four corners of the dock, so that by regulating the admission or egress of water to the respective groups, the dock is at all times kept perfectly level.

The engines and pumps are fixed within the vertical tubes, and the dock is constructed so that it can be separated in the centre into two halves, each provided with an engine and pumps. Each of these halves can be used to raise the remaining half readily out of the water for the purpose of cleaning and painting or repairing.

The advantages of this dock are sufficiently obvious:

1. With one dock any number of vessels can be docked and deposited high and dry out of water on wooden platforms, in a convenient position for cleaning and repairs, along the waste sloping shores of a river or dock.

2. The provision of an additional length of staging, at a comparatively nominal cost, is equivalent to the building of an additional dock.

3. As the dock is used ordinarily for lifting vessels on to the stage, it can be kept at all times ready to receive disabled or other vessels, which can be at once deposited on a stage, and the dock left free for further use, and in this respect has a great advantage over all other descriptions of graving docks.

4. A vessel can be placed upon the staging, cut in two, and readily lengthened by lifting one half further along the staging by means of the dock.

5. Vessels can be conveniently built on these stages on an even keel and launched without the slightest strain, and without the risk and cost of launching, or the space required for the formation of ordinary ship ways.

6. The dock with or without a vessel may be readily transported from place to place for the purpose of raising or depositing vessels at different points.

7. The dock will not under any circumstances sink even if all its valves be intentionally left open.

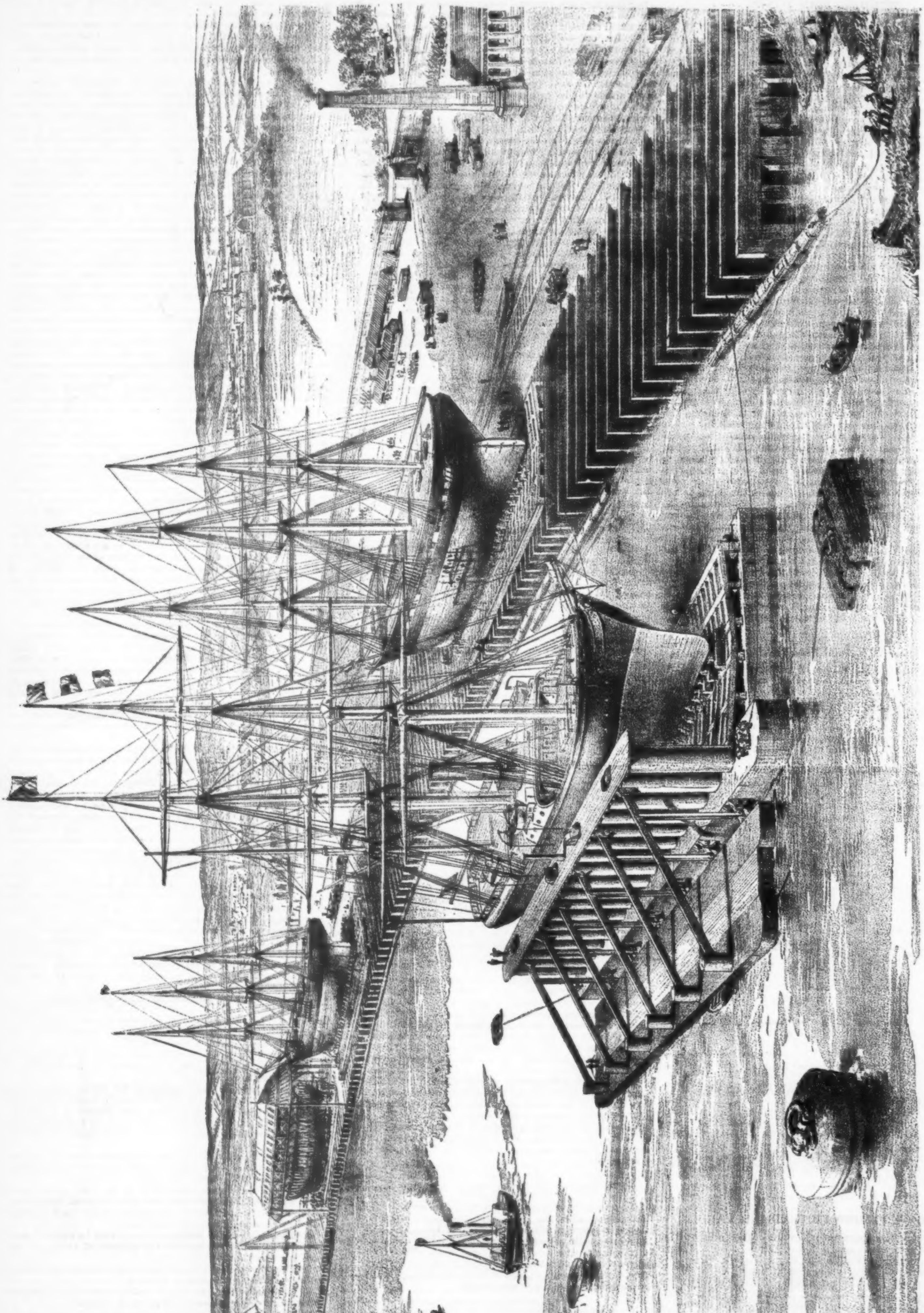
8. One half of the dock can be readily raised level upon the other half for the purpose of cleaning or repairs.

9. By the use of air, which may be stored in some of the cylinders under compression, a vessel may be raised, sighted, and lowered again in less than an hour.

10. These docks, if constructed in the first instance too small for the requirements of trade, can be at any time enlarged to any extent at the same rate per ton as the original cost.

11. The docks are capable of receiving vessels of any size or length, or of a width too great to pass through ordinary dock gates; such for example as circular ironclads of 100 or 150 feet diameter.

12. Lastly, in point of price, this dock is without any rival.



NEW TUBULAR FLOATING DRY-DOCK AND DOCKAGE SYSTEM.—BY LATIMER CLARK AND STANDFIELD.

A DESCRIPTION OF THE GREAT ROOF OF THE NORTHERN OF FRANCE RAILWAY TERMINUS AT PARIS, WITH REMARKS ON CURVILINEAR ROOFING.

[*Concluded from page* 634.]

CURVILINEAR ROOFS, presenting to the eye more or less of the character of the arch, but which in reality does not belong to them constructively, have almost universally been adopted in England for large roofs, instead of those covered by plane surfaces, presenting more or less the character of M. Lejeune's roof, as above described. This preference, however, has been due probably more to accident and to the hurry with which some of the earlier of these large roofs were erected, than to any solid grounds of preference, constructive or æsthetic. Designs for curvilinear roofs in iron were laid before Sir John McNeil, C.E., as early as 1847, and proposed for his adoption at the metropolitan terminus of the Great Southern Mr. R. Turner, of Dublin; we believe about 1849 or 1850. Except in so far as the adaptation of iron to their construction, there was really nothing new, long prior to this date, in the conception of curvilinear or arched rib roofing. Swiss and German bridges of carpentry roofed over above, and carrying the floor beneath, and constructed of two such ribs, of which that over the Rhine at Schaffhausen was a well-known example, were many of them fabrics of considerable antiquity; and the roof of the great riding-house at Moscow, constructed by order of the Emperor Paul in 1790, illustrated by Tredgold and Rondelet, "L'Art de Batir," tome IV., pl. 116, was a very fine example. It contained, no doubt, an immense mass of timber, but there was much boldness in constructing at all in timber a roof of 235 ft in clear span, one which we believe was never exceeded until the completion of Mr. W. H. Barlow's great roof at the St. Pancras Terminus, London, the clear span of which is 240 ft.—Fig. 33. We have assembled in diagrams, and for the purpose of the few critical re- these systems are to be found in Mr. Turner's roof of the Lime-street station at Liverpool, in which the entire system of rib trussing consists in wrought-iron members pendant radially from the arched rib, whose function is chiefly to hold up the main polygonal tie bar. These, therefore, act as ties rigidly connected at top with the rib and at the opposite end with the tie bar, but which, by the introduction of the slender diagonal stays above the bar, also play the part to a small extent of compressed members. This system, shown in Fig. 34, though in some respects not economical in iron, is perhaps quite as good structurally, and far better æsthetically, than any of the modifications which have been subsequently de signed and employed. The span of this roof is 153 ft. 6 in. Fig. 35 shows the great roof of the New-street station at Birmingham, constructed by Messrs. Fox & Henderson, under the authority of Mr. Baker, C.E., of the London and North-Western Railway, the general design of which—or at least the elaboration of the details—is attributable to Mr. E.

FIG. 32

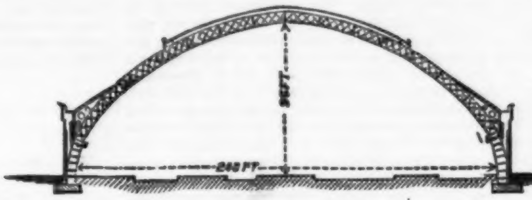


FIG. 33

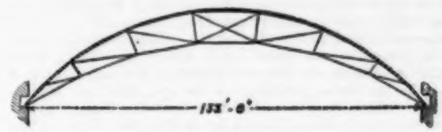


FIG. 34

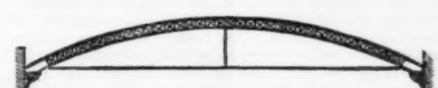


FIG. 37

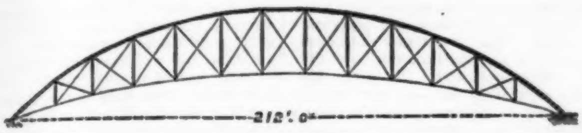


FIG. 35

FIG. 36

FIG. 38

FIG. 39

FIG. 40

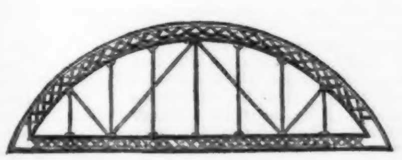


FIG. 41

FIG. 42

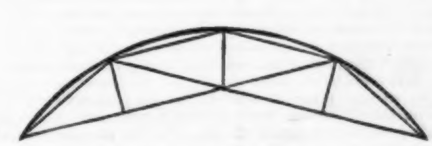


FIG. 43

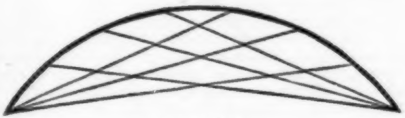


FIG. 44

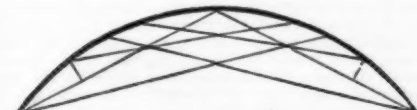
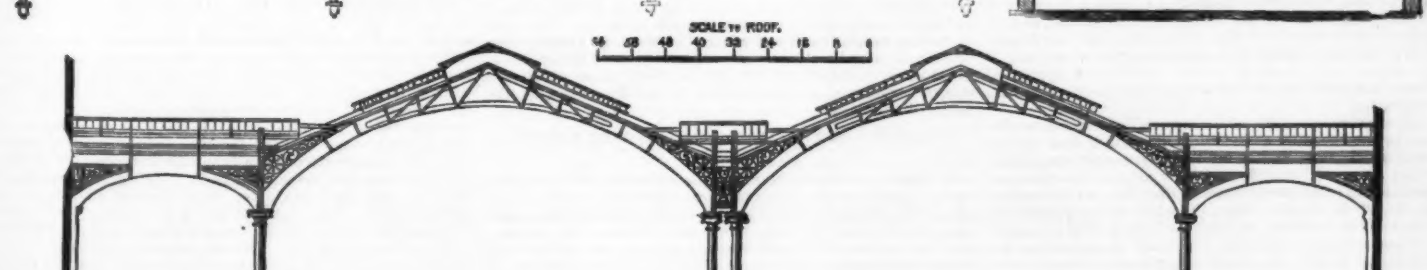


FIG. 45

FIG. 46

FIG. 47

FIG. 48



and Western Railway of Ireland; but such form of roofing, even of only 175 ft. span, was then deemed hazardous, and the preference was given, mainly, however, on grounds of economy, to cover in the same surface, comprising somewhat more than two acres, by several flat-surfaced roofs of moderate span, much like those which were adopted at the Euston-square station of the then London and Birmingham Railway, and elsewhere. The appearance, however, of a clustering together of such roofs of small span, and especially, as at Euston, where they cover irregular pieces of ground, is so mean, and the number of supporting columns so great, that larger spans and more dignified forms of construction were instinctively forced upon engineers, and curvilinear roofs of large span were at once unhesitatingly adopted after the way had been shown, and the practicability of such designs demonstrated by the construction of the curvilinear roof of the Lime-street station at Liverpool, designed and executed by marks to follow, several of the more noteworthy of these curvilinear roofs, chiefly constructed in England or from English designs. Roofs of this sort may be roughly divided into three classes: (1) those in which an exterior curved rib, of depth and scantling too slight for its own stability and resistance to extraneous forces, is rendered sufficient for these by the attachment beneath it of a complex system of trussing, consisting both of struts and ties, but whose main member is a heavy polygonal—as to its length—tie bar extending between one extremity of the rib and the other, and held up in position above the chord line by the other members of the truss, the main compressed member being the rib itself. (2) A curved rib, with a plate web uniting its upper and lower members, or an open lattice rib, which may be either sufficiently deep and strong to constitute alone the system of a principal rafter; or (3) a rib of either of those forms further strengthened by the application of trussed framing. Examples of the first of A. Cowper, M.I.C.E., then in the employment of the above firm. The clear span of this roof is 212 ft. The system of trussing of the principal rafters presents much similarity to Mr. Turner's design, the main point of departure being that the members which sustain in position the main tie bar have been placed not normal to the curved rib, but all parallel to each other and perpendicular to the horizon, and that double or cross diagonals are introduced in every bay between these. The construction here adopted is practically identical with that of the roof of the Charing Cross railway station and of that of the Cannon-street station, both of which emanated from the office of Sir John Hawkshaw, but the elaboration of the details of which may we believe be attributed mainly to Mr. Joseph Phillips, under whose direction these roofs were executed while he was in the employment of Messrs. Cochrane, the contractors for them. The span of Charing Cross roof is 162 ft., and of Cannon-street—Fig. 36—193 ft.

The earliest examples, so far as we are aware, of the second class—namely, curved ribs of lattice-work—are attributable to an American engineer, Mr. Osborne, who employed roofs of this design of considerable span upon American railways, the only subsidiary member in which was a single tie bar forming the chord of the arc, with a single suspending rod at the centre to keep it in line—Fig. 37. Fig. 38 reduces this system to its simplest possible form, being nothing more than a curved lattice girder, the non-spreading of the extremities of which depends upon the transverse stiffness of the girder itself, a construction which for large spans cannot be recommended. The roof of the railway-station at Amsterdam, Fig. 39, also belongs to this class, being, in fact, only a curved Warren girder instead of a lattice girder, the span of which is 120 ft. Fig. 40 is a roof over part of the Victoria station of the London, Chatham, and Dover, and Great Western Railways, the span of which is 127 ft. This design, we believe, emanated from the office of Mr. Joseph Cubitt. It consists of two main members, a somewhat attenuated lattice curved rib, and a single polygonal main tie bar, kept in position by the suspending rods at somewhat frequent intervals, whose directions are radial to the curved rib. This design, though it may be placed in our class No. 1, differs essentially from a rib with a system of diagonal trussing beneath it. As a whole, it is far more pleasing to the eye than any one of the roofs to which we have already referred. Fig. 41 shows the form of arched rib employed for roofing the great rolling shops at the Barrow Iron Works, the span being about 60 ft., and the distance between these principals about 30 ft. The arched ribs and tie both consist of double flitches of lattice-work at some distance apart, and the vertical and diagonal members connecting these, of single lattice webs transverse to the plane of the principal. This roofing is of very massive scantling, with a view to the principals being employed without fear as supports for hoisting heavy objects from any point of the floor; but heavy as they are, these principals produce a very pleasing effect from the obvious impression of fitness to the purpose intended, produced by every member. It is often said that taste is intuitive and subject to no rules, and therefore not amenable to criticism. In structural forms, however, if not everywhere else in the regions of nature and of art, simplicity, fitness, and symmetry of parts are elements which, whether articulately or not, press themselves upon the eye of every observer, and in proportion as they are present or absent, give rise to sensations of pleasure or of pain with which the structural objects presented affect the observer.

In highly complex structures, such as the trussed framing beneath these arched ribs, absolute symmetry may not be attainable, yet order and mechanical law in the departure from it should always at once impress itself on the eye of the observer if his imaginative faculties are to be gratified by the design, while an attempt to preserve a certain law or order in the departure from symmetry in both Fig. 34 and Fig. 40, viewed in respect to each half of the design, may be traced, and most so in the latter. In the design No. 35, and in the Charing Cross and Cannon-street roofs, almost nothing of this impresses the observer, whose eye is distracted, and his sense of purpose and fitness painfully disturbed, by finding interlacing members meeting or intersecting in ways which suggest nothing but feebleness, want of purpose, and confusion; and when we painfully try to analyze the complicated roof, we find its purpose resolves itself pretty nearly into a set of elaborate devices to maintain the one effective member of the whole, namely, the main tie bar, out of the right line—that is, out of the naturally effective condition of the chord of the arc. The radial struts in Mr. Turner's Liverpool roof satisfy our sense of fitness in so far as they occupy the true positions for the work they declare themselves to perform, however insufficient may be the apparent use of that work, namely, the looping up the tie bar into a polygon. But what can be said as to the position assigned to the corresponding members or struts in the Birmingham, Charing Cross, and the Cannon-street roofs, in which for no structural or other apparent purpose, except that they may be all parallel to each other and vertical, these are found meeting both the arched rib and the polygonal tie bar at angles the most various and perverse in every instance, and such as are constructively bad, being in no instance either normal to the arched rib or to the polygonal tie bar.

In these matters, every observer must, of course, form his æsthetic judgment for himself, and as we have said, that may scarcely admit of disputation; we, however, venture to state boldly that the impression made upon ourselves by the *ensemble* of these roofs is that of unmixed ugliness, partly derived from the unsymmetric confusion we have already referred to, partly from the appearance of palpable weakness, produced by the convergence nearly to a point of the curved rib and polygonal tie bar at the springings of the roof, so that the impression is conveyed that where the structure is subjected to its greatest strain it is apparently weakest, and it may be added that every structure in which a system of right lines is united with curved lines, results in the ugliness of incongruity.

The appearance internally of these curvilinear roofs might, perhaps, be improved by abandoning altogether this system of looped-up tie bars and tieing together the extremities of the arched rib as well as stiffening it by means of a system of straight diagonal and partly intersecting ties, as illustrated in Figs. 42, 43, 44, 45, 46. Figs. 42 and 43 are applicable to spans up to 80 ft. or 90 ft., and Figs. 44, 45, and 46 are applicable to larger spans. In these, nearly all the members are in tension, the arched rib itself being almost the only compressed member, and every portion of the system declares to the eye of the observer its purpose, and its evident fulfilment of that in the simplest manner, namely, by a tensile strain in the direction of its length. We commend this suggestion of a class of design, which has some claims to be considered new, to the attention of those concerned with large curvilinear roofing. The practical man will, we think, discern at once that a great deal of forge work and complication found in the roofs which we have above criticized might here be saved, and that rolled flat bars might not ungracefully be employed throughout these structures. Besides æsthetic ugliness, there seem to us to exist other objections of a much more material and practical sort, which have not yet met with sufficient consideration in reference to these curvilinear roofs. They but ill adapt themselves to a slated covering; from the continually increasing angle with the horizon of the curved surfaces from the crown to the springing, rain, and especially snow, shed themselves of with a velocity which, even in our climate, proves occasionally inconvenient; access to the roof's surface near the springing is rendered difficult, either for the removal of snow or for repairs, by the steepness of slope at these parts, whereas in a flat surface roof, with an angle of pitch not much exceeding that of M. Lejeune's design, every part of the roof is easily accessible, and a man can stand upon it everywhere with safety. The acoustic effect, however, of these curvilinear roofs, as applied to railway purposes, is that in which they contrast most unfavorably with flat surfaced roofs.

The blowing of railway whistles within station buildings is always a serious annoyance, which, though perhaps not admitting of absolute removal, might certainly be much reduced and mitigated upon all our railways. So rooted, however, do our habits become when once established, that there is little chance of reform in this respect; the consideration, therefore, becomes the more important so to adapt the internal forms of the roofs of our great railway stations to this necessary noise that it should produce the least distressing effect upon the ears of those beneath. Now, if we were seeking for the form that should produce the maximum amount of tumult and distressing noise in every part of such a station, it would be to cover it by a cylindric surface; the same acoustic phenomena in the reverberation of sound that are well known to every one in the whispering gallery of St. Paul's are found in all these roofs, the chief difference being that the transfer of the rays of sound is chiefly in a vertical instead of a horizontal plane. Let a railway whistle be blown anywhere beneath such a roof, the sound is not uniformly diffused in all directions through the surrounding air, decaying, with distance, in something like a sub-duplicate ratio, but the pencils of sound rays converge in directions transverse, or nearly transverse, to the length of the cylindric roof, and become concentrated at various points, and are often found far more distressing to ears there situated than to those within a few feet of the engine whistle. The extent of this reverberation is much augmented by the general custom or necessity of constructing the whole interior surface either of glass or of corrugated iron, both highly resonant materials, little extinctive of sound; and the distressing effects are further augmented by the very insufficient height sometimes given to these roofs in England. Thus the highest point beneath the crown of the Birmingham roof is about 75 ft., and that of the Charing Cross roof about the same. The height of the same point in the Cannon-street roof is considerably more, being about 105 ft.; but the effect of height in this last is, to a great extent, neutralized by the excessive curvature given to the roof, the versed sine of which, from the springing level, appears to be no less than 60 ft., or a little less than one-third of the span. In the Birmingham roof, with its numerous lines of rails and ceaseless traffic, the effect of this reverberation and reflection of discordant noises is no imaginary evil. We have ourselves been beneath that roof occasionally when a railway porter's voice, shouting at his highest pitch in the endeavor to give instructions as to where a particular train was to be found, was perfectly inaudible to those standing close to the man.

Beneath a flat-surfaced roof, such as that of the Northern Railway of France, there is no local concentration of sound originated at any particular point, and local noises are diffused nearly uniformly in all directions, and heard with an intensity inversely proportionate to the distance from their origin; hence, great height beneath the ridge in such a roof tells with full advantage, the distressing effect upon the ear of whistling and of the whirr of escaping steam, etc., being diminished roughly as the square of the height. So long as whistling continues to be deemed necessary, *discord* must be continued to be added to the ear-piercing scream, whatever be the pitch of the whistle itself; for the note emitted by the whistle will be heard by an ear beneath the roof at a higher or a lower pitch as the engine, in rushing by, approaches to or recedes from the hearer. This evil of discord cannot be avoided in these large roofs when of very great length, but the *range* of discord would be diminished by employing trumpet-toned whistles having a low key, and those only, whether entering or departing from beneath the roof. There can be no doubt that other curvilinear forms never yet attempted might be adapted to the roofing of great railway stations, which would obviate, to a great extent, these annoyances of concentrated noise, and might at the same time originate a new style of roofing for such buildings, which, in the hands of a competent architect, might be made extremely ornate and architecturally effective, without involving immoderate outlay.

A succession of iron-ribbed glazed, or partially glazed, domes, as shown in longitudinal section in Fig. 47, and in transverse section in Fig. 48, might spring from a nearly flat platform, which might be even of asphalte, laid on slate slabs supported by an iron platform resting on transverse bracketed girders connecting the side walls, from which the domes would spring, the opaque portions beneath these platforms being ceiled in stucco, the ornamentation of which would roughen its surface and so deafen sound; and no concentration of sound rays could take place, except directly beneath the centre of each dome, and but little propagation of sound could take place beneath any one dome except by direct diffusion longitudinally to the spaces beneath the other domes. This form of roofing would lend itself admirably to a high class of decoration in certain styles, more especially those of arabesque or Moorish architecture, or the heavier forms of Roman domed structures, as exemplified in the Pantheon or the baths of Caracalla.

LIVERPOOL-STREET STATION, GREAT EASTERN RAILWAY, LONDON

As tending to render more complete this article upon large roofs, we give in the annexed cut an elevation of that erected at the Liverpool-street station of the Great Eastern Railway, which forms the junction point between that railway and the metropolitan underground system, with the several branches divergent therefrom. This roof is from designs of Mr. E. Wilson, M.I.C.E., and our illustration, which appeared with the elevation in *The Engineer* for 11th June, 1875, page 404, is sufficient to give a general idea of the design which, though not in all respects unexceptionable, presents marked improvement upon nearly all preceding railway roofs in London, being the first instance in which the straight inclined rafter system, combined with curved sustaining ribs, has been employed. The entire roof covers an area of about 730 ft. in length, by about 314 ft., with an extreme height to the ridges of the main roof of about 80 ft. In width the roof consists of four spans, two of which may be called great or main spans, each of these being about 109 ft. in clear span. The two roofs are supported on three ranges of columns, the central range, or that between the roofs, consisting of double or coupled columns. At one side of these is a small curvilinear roof with straight girders, and somewhat similar in design to the main roofs; on the other side is a roof of still smaller span, but similar in design. The distance apart of the columns and of the principals which surmount them, taken in the lengthway of the roof, is about 27½ ft. These are crossed and connected at intervals by light lattice purlines resting on the straight principal rafters, which form the upper member of each principal, and which by intermediate struts and ties are connected with the curved lower member, each principal thus constituting a rigid frame free from all cross ties or other unsightly objects beneath the lower contour line. The columns have octagonal bases rising to a considerable height, above which they are taper and round, with some ornamental members just above the bases, and with floriated capitals. Nearly the whole roof is covered with glass, the central portion is glazed with a greenish or adiactinic glass, the sash bars being straight along the slope of the roof. The remainder of the roofs at either side are glazed with colorless glass in Paxton or small ridge and furrow fashion, the ridges being up and down the slope, and the sash bars parallel to the length of the roof. The dark colors in which these roofs are painted seem to us very much to mar the effect which they might present if lighter and more judicious tints had been chosen; but as a whole the roof presents a marked improvement in design over every other station roof—unless, perhaps, that of St. Pancras—in the metropolis. It has not altogether the airy lightness and noble simplicity of the roof of M. Lejeune, but it affords all the acoustic advantage of a plane flat surface in place of a circular one as respects internal noises. Experience will prove whether there be any truth in the doubt which suggests itself to us that, notwithstanding its great height, the immense external surface almost wholly of glass may render it inconveniently warm in summer and cold in winter.—*Engineer.*

MASONRY ARCHES.

We are constantly reminded that an arch under certain conditions is not a structure to be trifled with. Once built, properly backed and consolidated, no structure can be more secure. An underground arch, or a tunnel having a compressing force all round it, is of all forms of arch the most stable and secure; and few instances of tunnel failure have occurred where the pressure of earth at the top has been sufficient to counteract the lateral forcing in of the sides and invert. Unfortunately, however, builders are too impatient to knock away the props and centring, and we may observe nine tenths of the failures have arisen from this rash and hasty procedure. As the strength of any structure is only that of its weakest part, so in tunnelling the strength and stability depends entirely on the mortar jointing, and not upon the harder material composing it. The driving in of slate into the outer edges of the arch joints or in the extrados of the arches is a method seldom followed, and the increased thickness of the mortar joints at this part is strangely disregarded. Unless the bricks composing the arch are gauged to a wedge-shaped form, nothing in the world but an incompressible material can make the arch or tunnel of brick any thing stronger than that of the mortar used. In fact, all our tunnels and arches depend on the degree of hardness acquired by the mortar. It is strangely overlooked also that the outer mortar jointing is the last to "set," on account of the moist soil reposing upon it. Cement is seldom specified, though we should unhesitatingly recommend it in cases where the gauged arch bricks are not used. Another source of weakness is the want of "tie" between the rings of brick which compose the thickness of the arch. Ordinarily the bricks are laid all "stretchers," and no headers are introduced to connect the half-brick rings. If the headers are at proper intervals, so that there shall be one course more of stretchers in the outer than in the inner rim between the header courses, it is sufficient. Hoop iron laid between the rings in both directions and radially is another way of strengthening arches. Sir Isambard Brunel showed the strength of hoop iron in a half-arch of bricks in cement, which stood out like a bracket to the immense projection of 60 feet.

But the commonest cause of collapse is the "striking" of centres before the mortar has had time to set; and this one act of carelessness has been attended with more calamities than even bad construction and jointing. Upon this point we would remark that the common practice of striking a centre in one piece by driving out wedges, so that the support of the arch is removed all at once, is the most suicidal practice that can be adopted. The only safe course is to remove the support by degrees from the arch by laggings resting on the ribs through the intervention of screws, so that the least sign of unequal pressure may be watched with the greatest care, and the support retained as long as desirable. Till this method is adopted universally failures of a disastrous and fatal kind must continue to take place. Lately a very similar accident, also attended with fatal results, occurred at Manchester, where an arch of brick (6 feet 10 inches span, and 10¼ inches rise) collapsed four days after the centring had been struck. The arch carried a quantity of bricks, which were being used in the building operations, but the tie-rod was not secured.

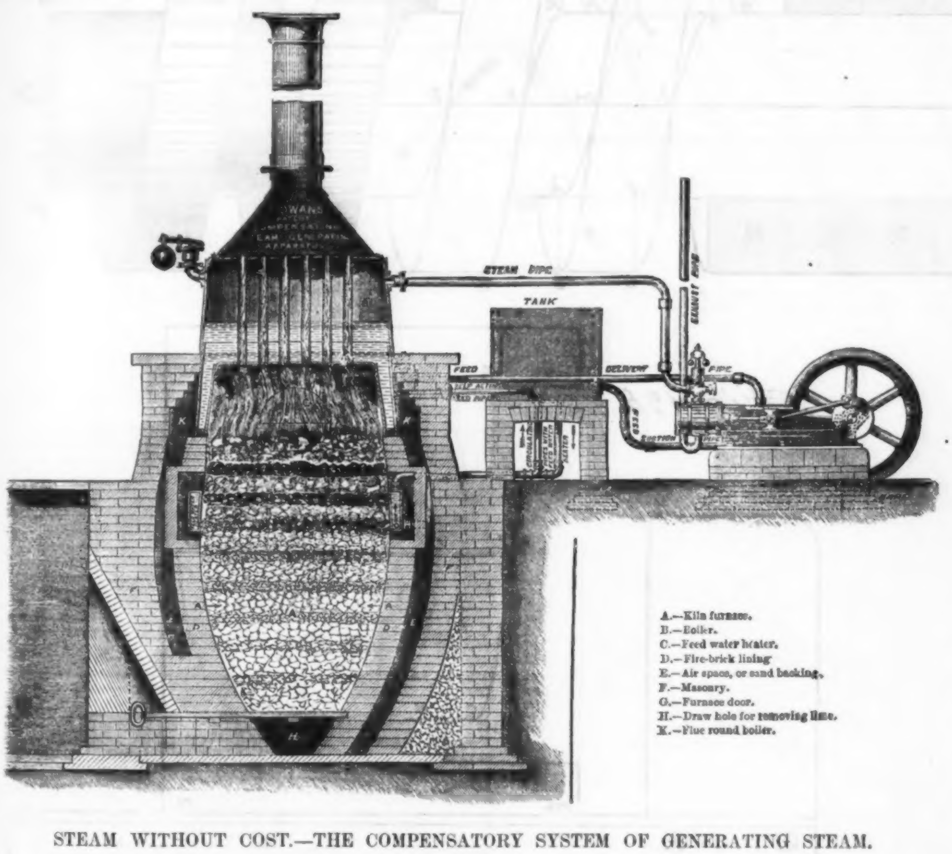
For the accident in the City, attended with the loss of three lives, and the burying of several men engaged in a sewer under the line, which lately took place on the Metropolitan Railway extension to Aldgate, we have scarcely sufficient evidence at present to attribute blame to any one. It appears certain, however, that the brick-work was "green," and that the mortar had not acquired sufficient hardness to permit of the removal of the supports while the work of filling-in was being carried on. Viewing the scene of the accident—which is in Devonshire street, in a line with Liverpool street, from which station the present extension is being constructed—we find the part that has given in is about the middle of the former street. The crown of the arch is about 5 feet below the roadway, and is of the usual thickness and construction, as far as we can gather. Various causes are assigned. Some say the dampness caused by recent rains has been the cause; others assign subsidence, several houses in Devonshire street being propped up; but the most probable cause is, to our minds, the removal of the shores or centring before the mortar had properly set. The tunnel arch being so close to the roadway level, and the lateral pressure of the houses being great, it is not improbable, indeed, that a slight collapse was the immediate cause of the disaster, especially if any supports were withdrawn. Messrs. Lucas & Aird are the contractors. We trust evidence will be forthcoming to show the cause of the failure in so simple a piece of tunnelling as that through Devonshire street.—*Building News.*

In the cloth manufactory of Renesson Fils, of Sedan, there is an electro-magnetic arrangement for stopping the steam engine. In the valve chest is a cock, on the axis of which is a little wheel, round which winds a weighted cord. The weight tends constantly to unroll the cord, and so close the cock, but is prevented doing so by means of a bar obstructing a tooth on the little wheel. This bar can be withdrawn by means of an electro-magnet, which can be worked at any distance from the machine with a constant, or, better, an interrupted current. In experiments made by a commission, the driving wheel did not make more than 1¼ to 1½ revolutions after sending the current.

STEAM WITHOUT COST.—THE COMPENSATORY SYSTEM OF GENERATING STEAM.

We give an engraving this week of Cowan's Patent Steam Generating Apparatus, which is now in operation on the premises of the Cowan Patents Company, at Garston, near Liverpool. The principle of the invention, though simple, is very ingenious and effective. The apparatus consists in the combination of a steam-boiler of vertical or other construction with a miniature lime-kiln, or, more correctly speaking, with a furnace so constructed that lime is manufactured in it, while at the same time steam is generated in the boiler by the heat arising from the combustion of the limestone and coal. The advantages which are claimed for this arrangement are that instead of the coal being used merely for the raising of steam, and being turned to useless refuse as in ordinary furnaces, it is utilized for the production of good lime, the marketable value of which is sufficient to cover, or nearly so, the cost of the fuel employed. As regards the boiler, it is asserted that a more steady and constant heat is maintained than under the old system, as much less stoking is required, it being necessary to charge the furnace only once a day, a consideration which is important in the economizing of labor.

In order to show the principle of the apparatus a small engine of 6 horse-power has been set up, and is at present used to drive a mortar mill, but it could, of course, be applied to a variety of purposes, such as driving stone-crushing machinery, draining mines and quarries, and pumping, for which latter purpose the company claim it would be very suitable, owing to the great economy of working. The boiler and engine have been at work for the past two months, and during that time we are informed the various experiments which have been made to test their capabilities have been highly satisfactory.



STEAM WITHOUT COST.—THE COMPENSATORY SYSTEM OF GENERATING STEAM.

The following return of one week's working of the apparatus will give an idea as to the actual cost, and the quantity of material used:

FUEL PUT IN FURNACE.

Coal (Welsh) at 14s. 3d. per ton....	3 t.	3 c.	1 q.	21 lbs.
Raw limestone, at 6s. 9d. "	8	11	2	4

RESULTS.

Good lump lime made, at 16s. per ton.	4	7	2	26
Slack lime, at 7s. per ton..........	2	9	2	26

The boiler was in steam for the whole of the 24 hours per day, but the machinery was only working for half that time. These figures show a small balance on the wrong side, but this is accounted for by the high price of the limestone as delivered in Liverpool, and it is estimated that in places situated nearer the lime-producing districts the results would be fairly remunerative, or at least would completely cover the cost of generating the steam. The principle, as described above, is not altogether a new one, the same company having already brought out a gas-making apparatus and a hot-water apparatus, both of which are in use on their premises, and by the latter of which about 21,000 ft. of piping in their greenhouses and vineries are at present heated. But this is the first time that the principle has been applied to the generation of steam as a motive-power, and it will be interesting to note to what extent it will compete with the old system. From what we have ourselves seen of it, we believe that if properly and judiciously worked it will undoubtedly lead to a much greater economy in the production of steam, and that it might be used very advantageously in many undertakings where this economy is an important consideration.—*Mining Journal.*

Among recent communications to the French Academy on the subject of Phylloxera was one by M. Thenard, describing the good results obtained by stripping off the bark of phylloxerised vines. This is easily done by means of a steel glove; and it frees the vine from the insect during the aërial evolution of the latter. The method might prove more advantageous than that which attacks the phylloxera during its subterranean life.

LESSONS IN MECHANICAL DRAWING.

By Prof. C. W. MacCord.

No. XXII.—(*Continued.*)

Having in a previous lesson explained the construction of the helix, we will now illustrate its application in the drawing of the screw.

The helix itself is sometimes called the "linear screw;" and the propriety of this name will be seen if we imagine a helix to be drawn upon a cylinder, and a narrow and shallow groove to be cut along the line: if we then put the point of a wire in the groove, and turn the cylinder, the wire will be made to travel along; or, if we hold the wire still, the cylinder in turning will advance endwise in the opposite direction.

In this illustration the groove is supposed to be very small, so as to resemble a line; but if it be made wider and deeper, this resemblance will be lost, and the surfaces bounding the groove will engage our attention, more perhaps than what is left of the surface of the cylinder. A little reflection will show that, from the manner in which the groove began and the manner of its growth, its surfaces must be made up of helical lines. The appearance presented will also vary with the form of the groove; we may make it at option a square, a triangular, or a semicircular groove, or indeed of any outline, each form giving rise to a peculiar surface.

In the practical cases with which we most frequently meet in mechanical details, the groove cut in the cylinder is either square or triangular, whence we have the familiar terms "square-threaded" and "V-threaded" screws: the triangle in the latter case being usually of such form as at once to suggest the letter V.

Perhaps as clear an idea of the nature of the surface to be represented may be obtained by the following illustration as in any other way:

Let us imagine a square rod of a perfectly flexible material, say like lead, to be wound round a cylinder, just as we supposed a wire to be in forming the helix or linear screw. If we suppose the material to be capable of so changing its form as to adapt itself perfectly to the conditions required in winding it, and that it is wound so that no space is left between the successive coils, we shall thus form a cylinder, larger than the one upon which the rod is wound, by just twice the thickness of the rod; the latter in fact will form a tube, the original cylinder just fitting the bore, and on the outside of the tube we shall see a helical line, which is the line of contact of the outer edges of the rod. As we have supposed the faces of the rod to be in contact all over in thus forming the tube, and the inside of the tube just fits the outside of the central core and coincides with it, there will also be, in fact, a similar helical line on the surface of the original cylinder, though it will not be visible from the outside; the pitch of this helix must be the same as that of the outer one, because the rod does not change its breadth, and, being square, its lower edges are just as far apart as the outer or upper ones.

Now, let us take two of these square rods, and place them side by side. We may then wind them upon a cylinder, just as though the two formed but one rod, of the same thickness as in the first case, but of twice the breadth. And if we wind them as before in such a way as to leave no spaces, but to make the successive coils fit and apply themselves closely to each other, we shall have also in this case a tub, on the outside of which we shall see *two* helical lines; the pitch of each helix will be just twice as great as in the first instance, so that one will not interfere with the other. On the inner surface of the tube, or what is the same thing, on the surface of the core or original cylinder, there will also be as in the first case a helix corresponding to each of those on the outside, of the same pitch, and marking the line of contact of the inner or lower edges of the square rods. Finally, leaving one of the rods coiled upon the core, let us unwind the other and remove it altogether; by this means we shall expose the helices last mentioned, and the space left between the coils of the remaining bar will be precisely such as would have been made by cutting a square groove of helical form in a cylinder of a diameter equal to that of the tube which we have supposed to be made in the manner above described. The central core with the remaining bar coiled on it make what we have spoken of above as the square-threaded screw.

What has just been described is represented in Fig. 194. C D is the axis of the core, or central cylinder, A B F E, upon which are wound the square bars seen in section at H, K, the part thus cut showing the thickness of the tube formed by coiling the bars round the core. At the right, the bar H is seen in elevation, this being the "thread" of the screw; the bar K being in that part of the figure unwound and removed, leaving the groove before mentioned. In order to exhibit the construction by which the drawing of this thread is made, we have shown at $adfe$ the section of the bar H, in lines, of which three, ae, df, fe, are dotted; the two, df and fe, are of course hidden, and the other one, ae, simply lies on the surface, and therefore, not being an outline, is in reality imaginary.

Now from the foregoing description, it will be seen that a is the outer edge of the bar, and when this is coiled up, that edge becomes a helix on the outside of the tube, or external cylinder; this helix is shown as ac, which portion lies on the front of the cylinder. It then disappears, but it emerges from behind the core, at p, and is visible, as shown at pbt, until it again reaches the lower outline of the outer cylinder.

It is needless to describe in detail the construction of this helix; it lies on a cylinder whose diameter is V W, and its pitch is determined by the consideration that as the bars were square, the breadth of the groove db is equal to the thickness of the thread ad. The pitch then is ab, and as ad is half of that, the point c is diametrically opposite to d. We might have dotted in the hidden part of the helix between c and p, but it would simply confuse the drawing to do so.

Now, d is the other edge of this bar or thread, and that edge becomes the helix $dsur$, similar to the other one, $acpb$; but by the removal of the bar K this helix is visible from s to u, where it disappears behind the inner cylinder.

We have now disposed of the helices on the outer cylinder; and from the manner of winding the bar on the core, it is seen that the lower edge of it, e, is formed into a helix on the surface of the core, or smaller cylinder, A B F E. The pitch of this helix is necessarily just equal to that of the ones on the outer cylinder—in making one coil, e must advance to k, bk being parallel to ae, and ek therefore equal to ab; also ef is equal to ad and therefore to one half of ek, so that in making a half turn the point e will advance to g, diametrically opposite to f, thus tracing the helix elg, which is visible only from e to l, where it disappears behind the helix ac; we have dotted in the section $gcsh$ of the thread on the lower side, in order to show that the originally plane vertical face of the bar is, by the operation of coiling it, twisted into a surface, of which the lines ae and gc are still vertical and straight; and the part lg of the helix under consideration is also shown in dotted lining. This helix goes on round its cylinder and reappears at k, the part gk, which might have been dotted in, being omitted to avoid confusion. Also there will be a similar helix, fmh, of which the first part fm is hidden by the outer helix dus; but at m it emerges and is seen in full until it reaches the lower outline of the cylinder at h.

By regarding the square screw-thread as formed in this manner, we believe that those who find difficulty in *realizing*, as the phrase is, the appearance of the surface—or, in other words, difficulty in forming a clear mental image of its peculiarities—may be enabled to surmount that difficulty. The power to do this is greater in some than in others, of course; but it is an essential one to any person who wishes to read outline drawings with facility. These drawings, consisting only of lines on a plane surface, and representing things from a point of view which is practically inaccessible, can not "stand out" and convey the idea of solidity without some exercise of imagination.

The particular surface here considered—that is, the warped or twisted surface of the screw-thread—may be, and usually is, defined and described in a very different manner from the one we have adopted, and in one sense it is a more simple manner, as we shall hereafter take occasion to illustrate. But we do not think it as simple, or at least as readily understood by those not familiar with problems of a similar kind. This one affords excellent exercise for this imaginative power, and in presenting it we have selected a mode of illustration which we think well calculated to aid the beginner in forming the idea of the appearance of the surface which his drawing is to represent. And should he need further assistance, there will be little difficulty in his making in the manner suggested a perfect model. This, if necessary, he is recommended to do; there is, perhaps, no better means of acquiring facility in the reading of drawings than to compare them with the actual objects drawn, and to study carefully the relations between the lines in space and their projections.

Supposing all this to have been attended to, and the student to be perfectly familiar with the steps of constructing the drawing of the screw, and to have gained in some way a perfectly clear idea of the surface, we will now call attention to some points bearing on the practical execution of such constructions.

In the first place, since the curved lines are helices, each of them must be tangent to the outline of the cylinder on which it lies; thus rb is tangent to the outer helix at b, and fk to the inner one at k. This of course is nothing more than has been already pointed out in explaining the construction of the helix; but we repeat it here, because, if the screw be drawn on any thing like as large a scale as it is in the figure, there is no error in the drawing more conspicuous or more hideous than that illustrated in Fig. 195, the helices, or their misrepresentations, exhibiting a malignant disposition to intersect the outlines of the cylinders, as at a, d, and e. The effect of this is utterly to destroy the apparent roundness of the screw, and to convey the impression that the end view will be of the form shown at A. We speak of the scale on which the screw is drawn, because it is very true that when it is small the effect of this error is not nearly so bad; and, indeed, there is a limit—as will afterward be seen—below which it is not at all worth while to pay strict attention to the exact curvature of the helix. But the trouble is that there are too many draughtsmen who pay no attention whatever to this point on any scale.

Another thing to be noted is, that the helix elg, Fig. 194, is *not* tangent to the helix alc, but intersects it at l. In the finished drawing, as shown in the coils of the screw-thread at the right, the dotted portion lg is omitted altogether; and it is very common to see the two helices drawn tangent to each other at what should be the intersection l. The result of this is not quite so disastrous as that of the preceding fault; but still the effect is bad, and it may as well be avoided as not. It will be observed that this point l really represents a line like ae—that is, an imaginary line of the surface, perpendicu-

lar to the paper in the side view of the screw, which gives an end view of this line, the true length of which is *l′ l′* in the other view; which may, perhaps, be more clearly realized if we imagine the screw to be turned a quarter round on its axis from the position here shown, in which case this line *l′ l′* will be vertical and exactly corresponding in position to *a e* at present.

Now, it will very often happen that in a drawing of mechanism a long screw of this kind has to be introduced. All the visible parts of the helices bounding the different coils or threads are but repetitions of each other, and to construct them all would be excessively tedious.

There are those whose exaggerated conscientiousness impels them to go through this drudgery, and possibly they feel the better for it. For ourselves, we regard such conscientiousness as a morbid development, and here state in emphatic terms that we look on such proceedings as a sinful waste of time. It is one thing, and a good thing, to be careful to the point of minuteness in determining correctly one of each of the different helices which are required; that done, if any more expeditious means can be devised for drawing the remaining ones, it is another and a wrong thing not to use them. And this is only a special case; the principle is perfectly general, and is applicable every day in the work of the professional draughtsman, which involves at the best a sufficient amount of tedious labor, and life is too short to be frittered away in following roundabout paths when there are short cuts leading to the same destination.

of the outer cylinder, as *o a*, *p b*, *u s*, etc., may be drawn by the same template merely turning over end for end; for by the construction of the helix it will be seen that *b p*, for example, when continued to *e* will pass through *m*, *s u* will pass through *x*, and so on.

When the curvature at the points of tangency, as *a*, *c*, *d*, *s*, is rapid, it may be found difficult to make that part of the template accurately, unless it be of metal, and difficult to use it in any case. Nor is it advisable to attempt to do so. Under these circumstances the proper course is to mark centres, as at *s* on the line *a e*, from which these sharp curves may be drawn with the bow-pen, and then with the template the remainder of the curve is to be drawn tangent to these arcs. A similar template may be made for the inner helices, and in this way what would otherwise be a very tedious operation may be disposed of in a comparatively short time.

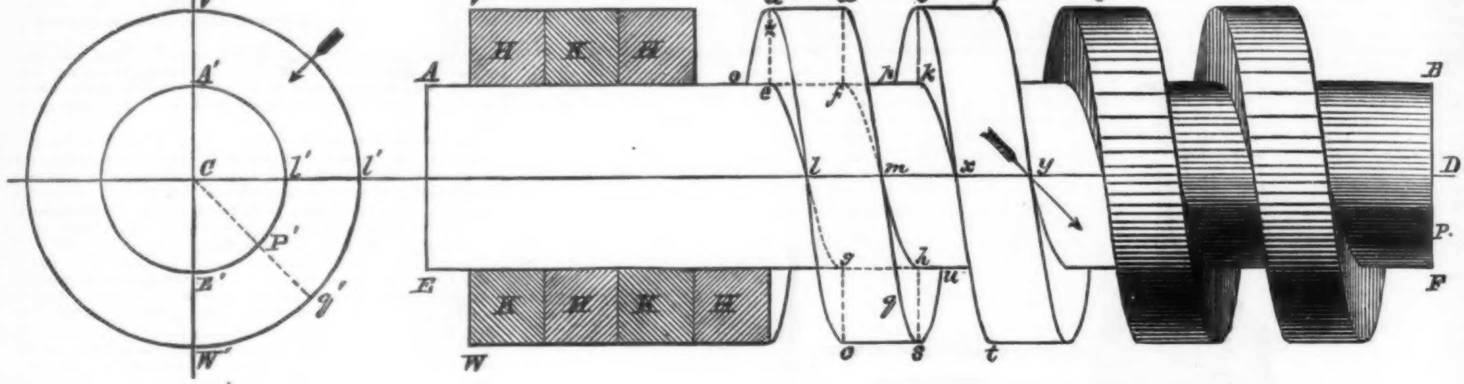
We have shown a part of the screw at the right fully finished in line shading; the top of the thread being merely a portion of the larger cylinder, and the bottom of the groove a portion of the smaller one, the shading of those parts is like that of Figs. 139 and 141. As to the sides of the thread: the light having the direction of the arrow in the side view will fall on the visible part of the left-hand side, and be excluded from the right-hand side, and the shading is upon the general principle before stated—that both lights and shades are stronger the nearer the eye is to the surface in question.

A little study will show that in this case the light can not reach all the parts, which are shaded as though it did reach light, and it is shaded as though it were, notwithstanding the fact that the thread is there and intercepts the light. Such a drawing may be regarded as incomplete perhaps in the comprehensive artistic sense, that since shadows exist they must be represented in a drawing which claims to show every thing as it is.

But it must not be forgotten that mechanical drawing for practical purposes is not picture-making. Its object is above all the clear indication of the forms and relations of the parts of the mechanism; shading of course greatly aids in doing this, and is not only admissible, but highly desirable, in general plans particularly; but it is not essential, and in detail drawings especially it should be sparingly employed. Still less are the falling shadows essential in even shaded drawings, though when judiciously managed they undeniably add much to the finish and effectiveness of what may be called mechanical pictures. Their accurate determination forms a branch of the science of mechanical drawing, which will be treated of when the time comes.

The screw shown in Fig. 194 is "single-threaded"—that is to say, the thread is formed by coiling only one bar round the core, leaving a space or groove of the same breadth as the thread. In Fig. 197 we have a core of the same size, and a thread also of the same depth and thickness as in Fig. 194, but the pitch is doubled. Thus the thread *a b* in one turn advances to *e f*, leaving a space, *b e*, equal in breadth to three times *a b*. In this space we may coil another bar, forming an intermediate thread, *c d*, which in one turn advances to *g h*,

FIG. 194.



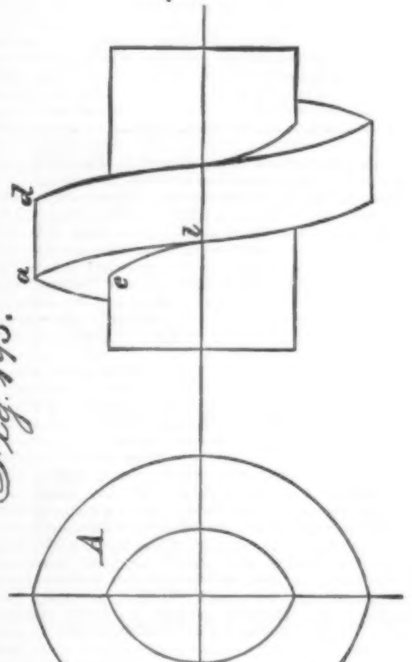
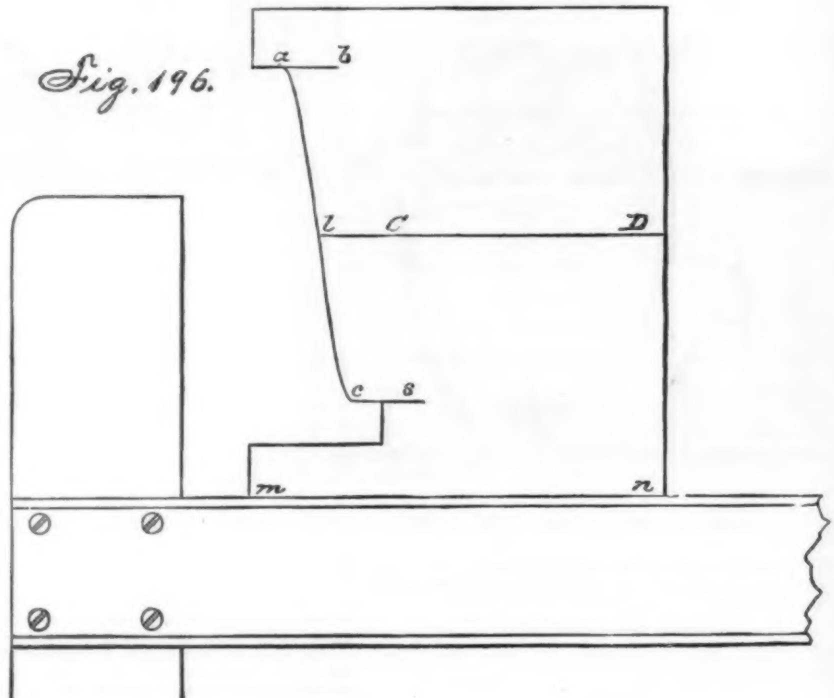


Fig. 195.

Fig. 196.



LESSONS IN MECHANICAL DRAWING.—No. 22.

In Fig. 196 we illustrate a simple method of saving time in the drawing of a screw of many threads. The figure shows a template, which may be made of card-board, of thin wood, or of metal; if of card-board, it will be rendered more serviceable by giving it a coat or two of shellac varnish. On this are drawn first the centre line C D, then the outlines of the cylinder, *a b*, *c s*; and finally the helix *a l c*: these letters correspond to the similar ones in Fig. 194. This helical line is the marking edge of the template, which must be very carefully cut or filed exactly to the line. The lower edge *m n* is parallel to the centre line C D, and at any convenient distance from it.

This template is shown resting on the blade of the T-square, along which it slides in the manner of a triangle. In using it, we have only to mark on the axis C D, Fig. 194, the points *l*, *m*, *x*, *y*, etc., through which the helices are to pass; then set the template against the blade of the square, slide the latter up along the end of the board (supposing the axis of the screw to be horizontal) until the centre line marked on the template coincides with the axis of the screw, and hold it firmly. Sliding the template now on the blade of the square, so as to bring its curved marking edge successively to the points *l*, *m*, *x*, etc., the helices can be drawn with great rapidity, and with a degree of uniformity which it would be difficult to attain were each one constructed. Moreover, the visible portion of the helices which lie on the farther side them; for instance, the bottom of the groove would evidently receive a shadow, the light being intercepted by the projecting thread.

This we mention to forestall captious criticism of the use of the expression "fully finished," just employed. In one sense it might be open to objection, since absolutely the projecting portions must cast shadows upon the depressed portions. But it is proper here to explain that in mechanical drawings the falling shadows are very frequently omitted altogether, and each visible surface is shaded as though the light could and did reach all parts of it, except those from which it would be excluded by some part of the body to which that surface belongs.

This is the method here adopted. For instance, by drawing the radius C *q′* perpendicular to the direction of the light in the end view, we determine *q′*, which being projected across to the helix *d m s* fixes the position of *q*, the termination of the shadow line on the helix *d m s*; and all that part of the front side of the outer cylinder which lies below the level of *q* is in the shade. Similarly the intersection of the radius C *q′* with the circumference of the inner cylinder at P′ is projected across to B F, determining P, the limit of the shadow line on the end of that cylinder in the side view, and all of that surface below P is in the shade, the light being kept from it by the form of the cylinder itself. Were there no thread coiled upon it, all the rest of the surface would be in the the distance *e g* being equal to *a e*, and the spaces *b c*, *d e* each equal to thickness of the threads.

This is called a "double-threaded" screw. The process of constructing the drawing is identical with that already explained for the single-threaded one, and it will be readily seen that by trebling the pitch we may add another thread, still another by quadrupling it, and so on.

These screws are both right-handed; but by reversing the direction of the helices, as explained in Lesson XX., they may be made left-handed with the same facility. It is also to be noted that although the space between the threads is equal to the thickness of the latter in the examples here given, and it is customary to make them so, this is not essential; and if for any reason it is desirable to make the threads wider or narrower than the grooves, or to make the breadth greater than the depth, these modifications in proportion may be made, without in any way affecting the process of construction.

Instead of unwinding one of the coiled bars in order to leave the groove, in the manner first explained of forming the screw, it will at once suggest itself that the same result would be effected by unscrewing it, since each part of the surfaces in contact advance and rotate uniformly. We may, then, imagine the bar K, for example, of Fig. 194, which, if continued, would form a thread precisely similar to that into which H is coiled, to be attached to the inside of a hollow

cylinder, whose diameter is V W, thus forming a nut, into which the screw whose thread is H will enter, fitting it exactly. A section of this nut is given in Fig. 198, in which the portions of helices that are visible are the same as those which lie on the farther sides of the cylinders in Fig. 194, and are therefore invisible in that drawing. A similar construction gives the nut for the double-threaded screw shown in Fig. 199; and these figures need no farther explanation than to call attention to the fact that no shadow lines are drawn on the helical portions, because the section is nearest the observer, and the surfaces of the threads recede abruptly. The reason for suppressing the shadow lines under such circumstances was discussed in connection with Fig. 157.

The construction of the V-threaded screw involves some considerations not yet spoken of, and will be described hereafter. In the meantime, the student is advised to practise carefully the drawing of the square-threaded one, varying the relative diameters of the inner and outer cylinders, which affects the curvature of the helices, until he can not only construct the curves, right or left handed, with facility, but make the lines fine, smooth, and continuous, above all paying attention to the perfect similarity of the different helices, since the slightest variation will produce a very bad effect—so bad indeed that a slight inaccuracy in the curve itself, if faithfully repeated, will be found far less conspicuous and offensive to the eye.

Fig. 197.

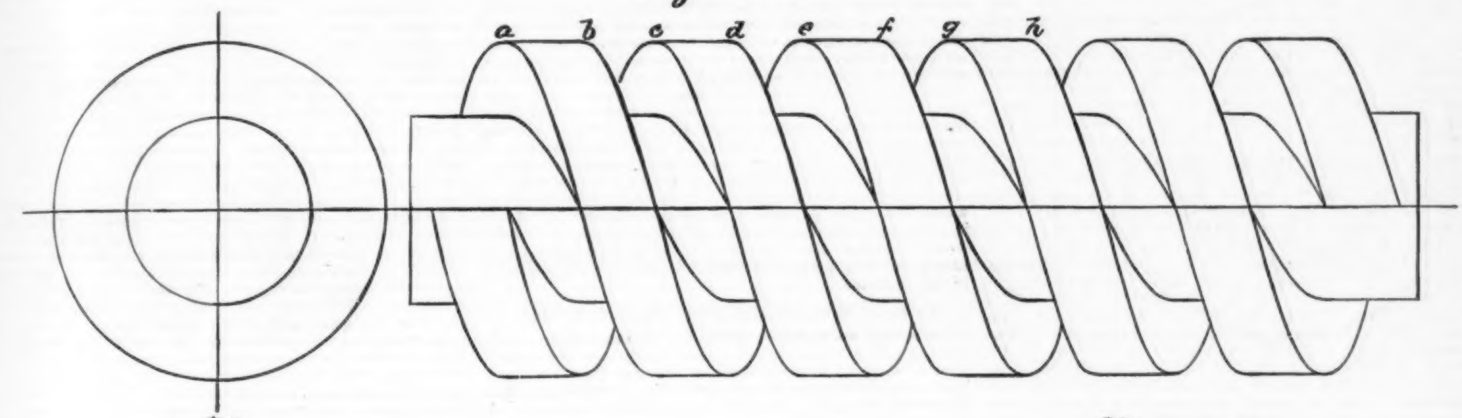


Fig. 198.

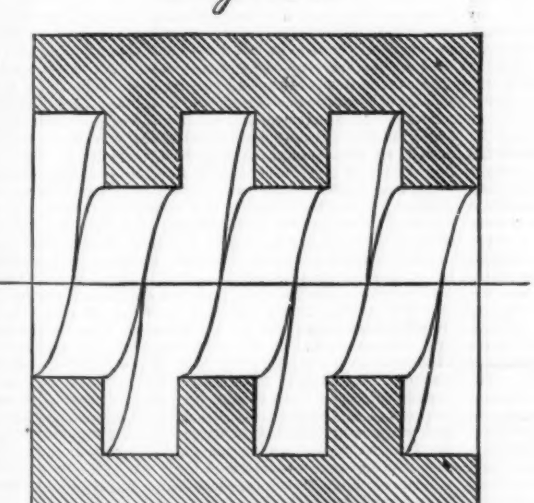
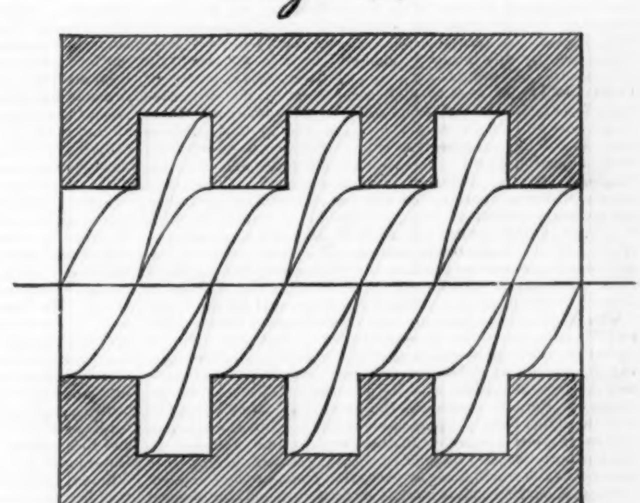


Fig. 199.



LESSONS IN MECHANICAL DRAWING.—No. 22.

PROFESSOR HUXLEY IN AMERICA.

THE THEORY OF EVOLUTION.

THE audience which listened to the second of Professor Huxley's series of lectures on the evolution theory, at Chickering Hall, New York, September 20, was a large one, and comfortably filled the auditorium and gallery. Not a vacant seat was visible anywhere within the hall. Besides being large in numbers the audience was also very appreciative, and the best token of this was to be seen in the careful attention shown by the auditors, and the earnestness with which they seemed to follow the speaker's train of thought. There was some slight applause as Professor Huxley stepped forward on the platform, and this expression of approbation was twice repeated, the last repetition being when the lecturer concluded his remarks.

The lecture was rather a difficult one to follow in thought, and imposed a constant strain on the attention of the auditors during the seventy-five minutes of its delivery.

THE SECOND LECTURE.

LADIES AND GENTLEMEN: In my lecture on Monday night (see SUPPLEMENT No. 41) I pointed out to you that there are three hypotheses which may be entertained and which have been entertained, in respect to the past history of life upon the globe. According to the first of these hypotheses, life, such as we now know it, has existed from all eternity upon this earth. We tested that hypothesis by circumstantial evidence, as we call it, which is furnished by the fossil remains contained in the earth's crust, and we found it was utterly untenable. We then proceeded to consider the second hypothesis, which I termed the Miltonic hypothesis—not because it is of any particular consequence to me whether John Milton seriously entertained it or not, but because it is stated in a clear and unmistakable manner in his great poem. I pointed out, too, that the evidence at our command has completely and fully negatived that hypothesis, as it did the preceding one. I confess that I had too much respect for your intelligence to think it necessary to add, that that negation was equally strong and equally valid, whatever the source from which that hypothesis might be drawn—from whatever authority it might be supported. I further stated that, according to the hypothesis of evolution, the existing state of things was but the last term of a long series of antecedent states which, when traced back, could be found to show no interruption and no breach of continuity; and I propose in this and the following lecture to test that no less rigorously by evidence at command, and to inquire how far that evidence could be said to be indifferent, and how far it could be said to be favorable to any demonstration; and, finally, how far it could be said to be demonstrated.

CUVIER'S ARGUMENT AGAINST EVOLUTION.

From almost the origin of these discussions about the existing condition and the causes which have led to it, in the animal and vegetable world, an argument has been brought forward as an objection to evolution, which we shall have to consider very seriously. I think that argument was first clearly stated by Cuvier, in his opposition to the doctrines propounded by his contemporary Lamarck. At that time the French expedition to Egypt had called the attention of learned men to the marvellous store of antiquities in that country, and there had been brought back to France numerous specimens of those mummified animals which the ancient Egyptians revered and preserved, the date of which, at a reasonable computation—a computation which, I may say, has been verified by all subsequent research—could not be placed at less than some three or four thousand years before the time at which they were brought to light. Cuvier endeavored to ascertain, by a very just and proper method, what foundation there was for the belief in a gradual and progressive change of animals, by comparing the skeletons and all the parts of the structures of these animals—ibises, dogs, and cats, and the like—with those which are now found living in Egypt, and he came to the conclusion—a conclusion which has been completely verified by all subsequent research—that in that space of time, at any rate, no perceptible change had taken place in the animals inhabiting Egypt. And he drew thence the conclusion (a hasty one) that the evidence of such fact was altogether against the doctrine of evolution. The progress of research since Cuvier's time has furnished far stronger arguments than those which he drew from the mummified bodies of Egyptian animals. An important case, for example, is to be found in your own country in the neighborhood of the magnificent Falls of Niagara. In the immediate vicinity of the whirlpool, and again upon Goat Island, in the superficial deposits which cover the surface of the soil and of the rock in those regions, there are to be found the remains of animals in perfect preservation, shells belonging to exactly the same classes as at present inhabit the still waters of Lake Erie. It is perfectly clear, from the conformation of the country, that those animal remains were deposited in the beds in which they are found at a time at which the lake extended over the region in which they are found, and that involves the necessity that they should have existed and lived and died before the Falls had cut their way back from the gorge of Niagara; and, indeed, it is possible to determine that at that time the Falls of Niagara must have been at least six miles further down the river than they are at present. Many computations have been made of the rate at which the Niagara is thus cutting its way back, and those computations have varied greatly; but I believe I am speaking well within the bounds of prudence if I assume that at its greatest rate of cutting back the Niagara Falls is not retreating at a greater pace than about a foot a year. Six miles—that is 30,000 feet; 30,000 feet at a foot a year is 30,000 years, and we are justified in concluding that no less a period than that existed since those remains were so left in the places to which I refer, since those were living animals, in which case we have a broad conclusion that for that immense period of time no change has taken place in these animals.

THE TERTIARY FORMATION.

But there are still stronger cases even than this. As we work our way through the great series of the tertiary formation we find species of animals identical with those living at the present day, diminished in number it is true, but still existing in a certain proportion in the oldest of the tertiary rocks; and not only there, but when we examine the fauna of the carboniferous epoch itself, we find the remains of animals which we cannot show to be in any respect different from those which live at the present day. This is the case, for example, with one of lump shell and terebratula which is found in the chalk, and which is continued with insignificant variations to the present day. Such is the case with the globigerina, the skeletons of which, aggregated together, form the great mass of our chalk in England. The globigerina can not be distinguished by any degree whatever from that which lies at present at the surface of our great oceans, and the skeletons of which, fallen to the bottom of the sea, accumulate and give us a chalky material. So it must be admitted that certain species of creatures living at the present day show no sign of modification for a period as great as that which carries us back to the period of chalk. And if we look not at mere species, but at what I may call types of animal form—such groups or species, so closely allied together, that we call genera, differ so little from each other that it needs the eye of the naturalist to distinguish the one from the other. If we pay attention to this, then, we find a vastly greater period more nearly allied in some cases to those persistent forms. In the chalk itself, for example, there is a fish belonging to the highest group of fishes which goes by the name of cericus. It is one of the most beautiful of the fossils found in our own English chalk. We find that fish is represented at the present day by a very closely allied species which are living in the Pacific and Atlantic Oceans. But we can go still further back upon this line of closely allied species. We find, for example, as I mentioned to you in my first lecture, that the coal, not only in Europe but in America, contains the remains of scorpions in an admirable state of preservation, and those scorpions are hardly distinguishable—I don't mean to say they are not distinguishable, but they require close scrutiny to distinguish them from the scorpions which exist at the present day. But if you try to form in imagination a conception of the length of time from the carboniferous epoch it is an astounding fact. More than that, at the very bottom of the silurian series, in what is by some authorities termed the Cambrian formation, where all signs of life appear to be dying out, even there, among the few and scanty animal remains which exist, we find species of mollusks, creatures which are so closely allied to existing forms that at one time they were grouped under the same generic name. I refer to the well-known lingula. Minute distinctions have been found, but

practically it belongs to the same great generic group which are at present found upon the shores of Australia. If we turn to certain great periods of the earth's history, as, for example, through the whole of this very mesozoic period, there are certain groups of reptiles which make their appearance at the commencement, or shortly after the commencement, of this period, such as the ichthyosaurus and plesiosaurus, in vast numbers. They disappear with the chalk from the whole of that great series of rock. They present no important modifications. Facts of this kind are undoubtedly fatal to any form of the doctrine of evolution which necessitates the supposition that there is an intrinsic necessity on the part of animal forms which once come into existence to undergo modifications, and they are still more opposed to any view which should lead to the belief that the modification in different types of animal or vegetable life goes on equally and evenly. The facts, as I have placed them before you, would obviously directly contradict any such form of evolution as indicated in these two postulates.

DARWIN'S SERVICE TO THE EVOLUTION THEORY.

Now, the great service which has been rendered by Mr. Darwin to the doctrine of evolution in general is this, that he has shown that there are two great factors in the process of evolution. One of them is a tendency to vary, the existence of which may be proved by observation in all living forms; and the other is the influence of surrounding conditions upon what I may call the parent form, and the variations which are thus evolved from it. The production of variations the cause of that production is a matter not at all properly understood at present. Whether it depends upon some intrinsic machinery, if I may use the phrase, of the animal form itself, or whether it arose from the influence of conditions upon that form, is not certainly a matter for our present purpose; but the important point is that, granting the tendency to the production of variations, then whether those variations shall survive and supplant the parent, or whether the parent shall survive or supplant the variations, is a matter which depends entirely upon surrounding conditions. If the surrounding conditions are such that the parent form is more competent to battle with them and to flourish with them than the derived forms, then, in the struggle for existence, the parent form will maintain itself, and the derived form will be extirpated. But if, on the contrary, the conditions are such as to be more favorable to the derived form than the parent form, the parent form will be extirpated and the derived form will take its place. In the first case there will be no progress, no material advance of type through any imaginable series of ages; in the second case there will be modification; there will be change of form. Thus we see that Mr. Darwin's view of the matter puts us in such a position that the existence of these precedent types of life is no obstacle in the way of the theory of evolution at all. In fact, the rightly-considered theory of evolution requires that such forms should be communicated. Take the case of these scorpions to which I was referring just now. No doubt, since the carboniferous epoch conditions have existed, such as existed then, in which scorpions flourished, in which they find themselves better off, more competent to deal with the difficulties of their way than any kind of variation from the scorpion type, and for that reason the scorpion has existed and has not been supplanted by any other form, and there is no reason in the nature of things as long as this world exists—if there should be conditions more favorable for scorpions than for any of the variations which arose from them—there is no sort of reason why this form should not exist as long as the universe itself exists. Therefore, this objection is no objection at all. Facts of this character and their examples belong to the class of indirect evidence; that is, they give no direct support to the doctrine of evolution, but they are perfectly capable of being interpreted in consistency with it. There is another order of facts of the same kind and susceptible of the same interpretation. The great group of lizards which abounds so much at the present day can be traced back through the whole series of form, as far as what is termed the Permian epoch, which is represented by the strata which lie just above the coal; and these Permian lizards differ so little—they do differ in some respects—but they differ so little from the lizards which exist at the present day (comparing the amount of difference between these Permian lizards and the present lizards, with the prodigious lapse of time between the Permian epoch and the present day) that it may be said there has been no appreciable change. But the moment you carry your researches further back in time you find no trace of any lizards whatever, no traces, in fact, of any true reptiles in the whole mass of formation beneath the Permian. Now, it is perfectly clear that if our existing palæontological collections—our existing series of stratified rocks—if they represent the whole series of events which have taken place on the face of the globe, such a fact as this directly contravenes the whole theory of evolution, because that postulate is that the existence of every form must have been preceded by that of some form very different from it. Here, however, we have to take into consideration that important fact, so well understood by Lamb and by Darwin—the imperfection of the geological record. It can be demonstrated as a matter of fact that the geological record must be incomplete; that it can only preserve remains found in certain favorable localities and under particular conditions; that it must be destroyed by process of percolation; that the remains must be obliterated by processes of metamorphosis, by which I mean that beds of rock of any kind crammed full, it may be of organic remains, may yet, either by the percolation of water through them, or by the influence of superabundant heat, if they descend far toward the centre of the earth, lose all trace of these remains and present the appearance of beds of rock formations, a condition in which there are no traces of living forms. Such metamorphic rocks occur in forms of all ages, and we know with perfect certainty when they do occur that they have contained organic remains, but that they have been absolutely obliterated. It is one of the most striking proofs with which I am acquainted of the imperfection of the geological record, and I insist upon it the more because those not acquainted with these matters are very apt to say to themselves, "Well, it is all very well, but when you get into a difficulty with your theories of evolution, you appeal to the imperfection of the geological record."

GEOLOGICAL FORMATION OF THE CONNECTICUT VALLEY.

I want to make it perfectly clear to you that that imperfection is a vast fact, which must be taken into account in all our speculations, or we shall be constantly going wrong. You will all see that singular series of tracks, which is copied in natural size, on the large diagram above me, and which I owe to the kindness of Prof. Marsh, with whom I had the opportunity recently of visiting the precise locality in Connecticut where these tracks occur. I am, therefore, able to give my own testimony, if needed, that it accurately represents the state of things which we saw. The valley of the Connecticut is classical ground for the geologist. It contains great beds of sandstone, covering many square miles, and which present this peculiarity, that they have evidently formed part of an ancient sea shore, or it may be a lake shore; and that they have been sufficiently soft for a certain time to receive the impressions of whatever animals walked over them and to preserve them afterward in exactly the same way as such impressions are at present preserved on the shores of the Bay of Fundy and elsewhere. We think they are tracks of some gigantic two-legged animal. You see the series of marks made alternately with the right foot and left foot, and you see that all these impressions are the impressions of three-toed feet, and each stride as we measured it is six feet and nine inches. I leave you, therefore, to form an impression of the magnitude of this creature, which must have walked along that ancient shore and which made those impressions. Now, of such impressions there are untold thousands upon this sandstone. Fifty or sixty different kinds have been discovered, and they cover a vast area. But, up to this present time, not one tooth, not a fragment of any one of the great creatures which made those impressions, has been found; and the only skeleton which has been met with in all these deposits up to the present time, after they have been most carefully hunted, is one fragmentary skeleton of one of the smaller forms. What has become of all those bones? We are not dealing with little creatures; for an animal that can make a step of six feet and nine inches is not easily lost. The bones must be or must have been somewhere. The probability is they have been dissolved and are absolutely lost. We have had occasion to work out a series of fossil remains, of which there are nothing whatever except the casts of bones, from which the solid materials of the bones have been dissolved by percolating water. It was a chance in this case that the sandstone was of such constitution as to set and allow the bone to be dissolved. If it had not been of such constitution, the bones and the beds of sand would have dissolved together, and we should have had no indication that such an animal existed. I know of no more striking evidence of the caution we must use in concluding, from the absence of organic remains in a bed, that such animals did not exist. I believe that a right understanding of the doctrine of evolution on the one hand, and a just estimation of the importance of imperfect geological record on the other, removes the difficulty; and the kind of evidence to which I have just adverted, and which allows us to believe in such cases, are what I might call of a negative and indifferent character—that is to say, they in no way advance evolution, but they are no real obstacle in the way of our belief in that doctrine.

CASES IN FAVOR OF THE DOCTRINE OF EVOLUTION.

I now pass on to the consideration of those cases which, for reasons I will point out to you by and by, are not demonstrative of the truth of evolution, but which may be such as must exist if evolution be true, and which therefore are, upon the whole, strongly in favor of the doctrine of evolution. If the doctrine of evolution be true, it follows that animals and plants, however diverse they may be, however diverse the different groups of animals, and however diverse the different groups of plants, must have been connected together by gradational forms, so that from the highest animals, whatever they may be, down to the lowest speck of gelatinous matter in which life manifests itself, there must be or have been a series of gradations which pass from one end of the series to the other. Undoubtedly that is a necessary postulate of the doctrine of evolution. But when we look upon animal nature as it at present exists, we find something totally different from this: we find that animal and plants fall into groups, the different members of which are pretty closely allied together, but which are separated by great gaps and intervals from other groups; and you can not at present find intermediate forms bridging over those gaps and intervals. To illustrate what I mean, let me call your attention to those vertebrated animals which are most familiar to you, such as mammals, birds, and reptiles. At the present, say these groups of animals are perfectly well defined from one another. We know of no animal now living which in any sense is intermediate between the mammal and the bird, or between the bird and the reptile; but, on the contrary, there is a whole sum of distinct grades by which the mammal is separated from the bird, and the bird from the reptile. The like holds good if you compare together the different divisions of these great groups. At the present day there are numerous forms of what we may call, speaking ordinarily, the pig type; and there are an immensely numerous variety of ruminants. Ruminants have their distinct grades, and pigs have their different characters, but there is nothing which comes midway between the pigs and the ruminants. The two groups are distinct. So if we take two groups of reptiles at the present day. We have crocodiles, we have lizards, we have snakes, we have turtles and tortoise, but we have nothing intermediate between the crocodile and the lizard, between the lizard and the snake, and between the snake and the crocodile, or, in fact, between any two of these. They are separated by absolute "breaks," as we say. If it could be shown that that state of things has always existed, it would be fatal to the doctrine of evolution. If intermediate gradations between those groups are not to be found anywhere in the records of the past history of the globe, it is so much strong and weighty argument against evolution; while, on the other hand, if such intermediate forms are to be found, that is so much to the good of evolution, although, for reasons I will put before you by and by, we must be cautious in assuming such facts as proofs of evolution.

It is a very remarkable fact that from the first commencement of the serious study of palæontology, down to Cuvier, for all that palæontology had shown, the group of pig-like animals and another group of ruminants were entirely distinct. But one of the first discoveries of Cuvier was an animal which he showed to be in a great many important respects intermediate in its character between the pigs on the one hand, and the ruminants on the other; that, in fact, research into the history of the past did, so far as to the extent which Cuvier indicated, fill up the gap between the group of ruminants and the group of pigs; and all subsequent research has tended in this direction, and which more and more fills up the gaps in existing series of mammals.

GROUPS OF BIRDS AND REPTILES.

But I think it may have an especial interest if, instead of dealing with these cases (which would require a good deal of osteological detail), I take the case of birds and reptiles, which, at the present day, are so clearly and sharply defined from one another, that there are perhaps no groups of animals which, in popular apprehension, are more completely separated. Birds, as you are aware, are covered with feathers; they are provided with wings; they have specially and peculiarly modified anterior extremities; they walk upon their two hind legs, and those limbs, when they are anatomically considered, present a great number of exceedingly remarkable peculiarities, to which I may have occasion to advert incidentally as we go on, but which are not met with or even approximated in any existing form of reptile. On the other hand, reptiles, if they have any covering at all, have a covering of scales or bony plates; they possess no wings; they have no such modification of their limbs as we find in birds. It is impossible to imagine any two groups apparently more definitely and distinctly separated. As we trace the history of birds back in time, we find their remains abundant in the tertiary rocks throughout their whole extent; but so far as any thing is known of the birds of the tertiary rock, they retain the same essential character as the birds of the present day. That is to say, the oldest tertiary birds come within the definition of our existing birds, and are as much separated from reptiles as our existing birds are. A few years ago no remains of birds had been found below the tertiary rocks; and I am not sure that some persons were not prepared to demonstrate that they never could have existed at an early period. But in the last few years such remains have been discovered in England, but, unluckily, in a very imperfect condition. In your country the development of the cretaceous rocks is enormous, and the conditions under which the later cretaceous rocks were deposited have been particularly favorable for the preservation of organic remains in a perfect condition. And the researches, full of labor and toil, which have been carried on by Prof. Marsh in these Western cretaceous rocks, of late years, have rewarded him with the discovery of forms of birds of which hitherto we had no conception. By his kindness I am enabled to put before you a restoration, every part of which can be thoroughly justified (these remains existing in the greatest beauty and perfection), of a bird about six feet high—a large bird—which existed during the later cretaceous epoch, and which, in a great many respects, is astonishingly like the existing diver, or grebe—so like that, had this skeleton been found in the Museum, I suppose, if the head had not been gone, it would have been put in the same general group as the divers or grebes of the present day. But this bird differs from the existing birds, and so far resembles reptiles in one important particular, and that is, that it is provided with teeth. These long jaws are beset with teeth, as you see represented on this diagram. Here is one of the teeth, in this. In that respect it differs entirely from any existing bird. Finding this Hesperonis with such characteristics, we are at once obliged to modify our definition of the classes of birds and reptiles. Before that, it could be said that a bird had such and such characteristics, among which was an absence of teeth. Discovering a bird with teeth shows at once that there were ancient birds, which, in that particular respect, approached reptiles more nearly than any existing bird does. The same rocks have also yielded another bird, which also has teeth in its jaws; the teeth in the one case being situated in distinct sockets; while this bird was a swinging bird, had very small wings, this was a flying bird, with very large wings; in all respects a bird, but differing from existing birds, first, in the fact that it possesses teeth; second, in the fact that the joints of its backbone, its vertebræ, have not the peculiar character and form of existing birds—articulate surfaces—but that they are concave at each end. And here, again, the discovery of this bird leads us to make another modification in our definition of the characters of a bird; they are not so far off from reptiles as we imagined them to be, knowing that such forms as these may exist. We know nothing whatever of birds later than this until we come down to the middle of the Jurassic period, and from that period we know a single bird which was first made known by the finding of a fossil feather. It may seem wonderful that such a perishable article as this should be preserved in the rocks; but in the fine matrix of the slate in which this bird occurred, so it was. For a long time nothing was known of this bird except this feather; but after a while one solitary specimen was discovered, which is now in the British Museum; but that solitary specimen is, unfortunately, devoid of its head, and we can not see whether it had teeth or not. But there is this wonderful peculiarity about the creature, that so far as its hind legs are concerned, it has all the most specialized characteristics that the bird exhibits in the hind legs, by which the bird is distinguished from the reptile; but when we examine the vertebral column we find it is unlike any existing bird, and like the reptile in possessing a long tail, fringed on each side with feathers. And a most remarkable feature when we come to examine that which represents the wing, and which in many respects is exceedingly like the wing of an ordinary bird, we find that that division of the wing which corresponds with the hand differs in some very remarkable respects from the structure which it presents in a true bird. In a true bird the wing consists of what answers to these three fingers of my hand—thumb and two fingers; and those bones which I am now touching are fused together into one mass—anchylosed, as we say, co-ossified; the whole apparatus except the thumb is usually bound up in a great sheath integument upon the forearm—in this fashion [illustrating]; this sheath integument supporting the feathers of the wing, and then the edge of the arm, and so forth, carrying the other feathers. It is in that way that the bird's wing becomes an instrument of flight. In this bird, the archeoptrix to which I am now referring, the pterodactyl, with the forearm like this bird, these fingers are not bound together; there are three, and they are all terminated by strong claws. So it is impossible to say how many fingers may have existed, but such as there are had the same structure as the anterior limb of a reptile, the feathers being attached to the arm bones. So that in this singular archeoptrix you have an animal which takes to a certain extent a midway place between a bird and a reptile. It is a bird so far as its hind limbs are concerned, it is a bird in a great many other peculiarities of its organization; it is essentially and thoroughly a bird in the fact that it possesses feathers. But it is not a bird, and it is much more properly a reptile, in the fact that its anterior limb has not undergone that modification which is characteristic of birds, but rather resembles the fore limb of a reptile. All these cases, so far as they go, you observe, are in favor of evolution, to this extent, that they show that in former periods of the world's history creatures existed which overstepped the bounds of our existing classes and groups, and tended to fill up the intervals which at present exist between them.

INTERMEDIATE FORMS BETWEEN BIRDS AND REPTILES.

But we can go further than this. It is possible to fill up the interval between birds and reptiles in a much more striking manner. I do not think that this is to be done in the way that some suppose—by looking upon what are called the pterodactyls as intermediate forms between birds and reptiles; I will briefly explain why I hold that opinion. Throughout the whole series of mesozoic rocks, from the end of the triassic upward, we meet with some exceedingly remarkable flying creatures, some of which attain great size, their wings having spans of eighteen or twenty feet or more. These are what are known as Pterosauria and Pterodactyls. I have a figure here of a very perfect specimen. You see as

animal with a bird-like head and neck, with a vertebral column which is sometimes terminated by a short tail, sometimes by a long tail, and in which the bones of the skeleton present one of the peculiarities which we have been considering the most characteristic of birds, namely, that of being excavated, having cavities that are full of air, what are called pneumatic cavities, evidently having reference to making the creature specifically lighter in its flight. Then, like a bird, this creature has a largish breast-bone, with a crest upon it, a shoulder-girdle, more like that of a bird ; but from that point inward, so far as I can see, the special bird-resemblance ends. A careful examination of the fore limbs, which are the instruments of flight—a careful examination of those fore limbs shows you that they are not bird's wings, that they are something totally different from bird's wings. Then, these are not a bird's posterior extremities, so far as we know them, but are rather essentially modified reptiles' extremities. You will observe that the forearm bone presents nothing that I need dwell upon. But the bones of the hand are very wonderful. There are four fingers represented, and the bones of these four fingers are large ; three of them are terminated by claws, while the fourth finger is enormously prolonged. Nothing could be more unlike a bird's wing than this. You will see at once from what I have stated regarding the character of a bird's wing that the plan of it is something totally different, and in fact, the wing is totally different. It was concluded by general reasoning that this finger was meant to support a web like a bat's web. Subsequent research showed that this was the case ; that it was devoid of feathers ; that the finger supported a web, and this ancient bird flew in the same manner as a bat. So, the pterodactyl, although it is a flying reptile, although it presents some points of similarity to a bird, yet it is so totally different from it in all those parts characteristic of birds that I don't think we have any right to regard it as one of the forms intermediate between reptile and bird. Such intermediate forms, however, are to be found by looking in a different direction. Throughout the whole series of mesozoic rocks there occur reptiles, some of which are of gigantic dimensions ; in fact, they are reckoned among the largest terrestrial animals ; some of them must have been forty or fifty—possibly more—feet long. Such was the megalosaurus, and a number of others, with the names of which I need not trouble you. There are great diversities of structure among these great reptiles. Some of them resemble lizards, and evidently walked upon all fours, and in such respect resemble the existing crocodile. But in others you can trace a series of modifications. What we call the haunch-bone, with its appendages and hind limb, puts on a series of modifications, by virtue of which it at length completely assumes the character of a bird's hind limb. In order to make this clear, I have had represented the hind limb of a crocodile, showing the haunch-bone with its characteristic form, and two other forms of pelvis, the ischium and pubis. That is the thigh-bone, these are the two leg bones. You will observe that the small bone of the leg which is here is quite complete and entire. Then comes the division of the foot that we call the tarsus, all the bones of which are separate and distinct ; and here come the four toes, which alone exist in the hind feet of the crocodile, and all those are separate and distinct. The foot is placed in this position in order that it may compare with these other limbs, but in the natural position of the crocodile's hind leg the thigh-bone stands out from the body, and the foot is flat upon the ground, so that the legs sprawl out, and the weight of the body hangs clumsily between them.

Now contrast this with what we find in the bird. The haunch-bone here is immensely elongated, and the vertebræ, the joints of the back-bone, between the two haunch-bones, are run together, united together, so as to form a solid support upon which the weight of the body rests. Then the bones which answer to these two become exceedingly long, as you see here, and are, as it were, swung backward, so that this bone passes in that position and that bone in this position, parallel with it. Then the thigh-bone becomes very short, and has a peculiar rib upon its outer articular surface at the lower end, and the rib fits in between the upper extremity of the small bone of the bird's leg and the great bone, and makes a kind of spring joint, which I dare say many of you have noticed in an ordinary fowl's leg. Then this small bone of the leg, the fibula, is quite large above, and becomes rudimental below, running out into a stile instead of being long and large and complete, as it is in the case of the crocodile. And then when we come to this part of the leg, to the bend of the foot, you find there are no separate bones such as you have here, but the end of the tibia, or large bone of the leg appears to end in a pulley, appears to be formed by a kind of pulley, and that place is played upon by a single bone, made of three pieces, and upon the extremity of that bone are attached these three toes ; there may be four in a bird. It is obvious that the contrast between the crocodile's leg on the one hand, and the bird's leg upon the other, is very striking. There is a great gap or interval between those two, but that gap or interval is completely filled up when you study the character of the hinder extremities in those ancient reptiles which have frequently been called dinosauria. I have here, for example, such a pelvis and such a hind leg as is possessed by the iguanodon. The form of the haunch-bone, you see, is unlike that of the crocodile, and is getting to be like that of the bird. While there are only two bones of the backbone to form the key of the arch of the haunch-bone in the crocodile, there are some six or seven here. Just as the form of the ilium or haunch-bone is intermediate between that of the crocodile and that of the bird, so is the character of the sacrum, as we call it, and of the vertebræ which lie between the two ilia. Then this bone, the ischium, in the crocodile, is represented in the iguanodon by a long bone which approaches in form and in its direction, the corresponding bone of the bird. The bone is represented by this elongated pubis, which also corresponds in form with that of the bird. Instead of the thigh-bone straddling out almost at right-angles to the body, as it does in the crocodile, the thigh-bone of the dinosaur lies parallel with the body, as it does in the bird, so that the head of the bird is at right-angles with the shaft. That arises from the necessity of throwing the weight of the body upon these two great levers. There is a ridge upon that portion of the femur which plays between the upper end of the small bone of the leg and this large bone, exactly as in the bird. Again, this small bone of the leg becomes thin, not actually complete, but thins off below, and instead of these bones being all separate and distinct, that bone which we call the astralagus here has the shape of a pulley, and is so fastened on to the end of the tibia that you have some difficulty in separating it. In other words, until you have separated this bone from the tibia, the form of this shin-bone or tibia of the dinosaur is exactly the same as of the bird ; and if you examine a young bird, or an ordinary fowl, as it is brought to the table, you will find that you can very easily get this pulley off the extremity of the shin-bone, and that then the shin-bone of the bird is exactly like the shin bone of the dinosaur. So again, the number of toes becomes reduced, and the middle toe becomes longest, and as in some birds all these four toes are turned forward, but they may be reduced to three ; but these bones, which in the crocodile are quite free, can play easily, in the dinosaur become so that no play is possible. In fact, we have a stage between the free condition of the crocodile and the anchylosed and united condition that you have in the bird. So that in all these respects—and if this were the place in which to pursue the researches in comparative anatomy, I could follow out the parallel in the other sets of organs—in all these respects the dinosaurian holds a place between the reptile and the bird. Finding this modification of the hind limbs, finding that in many of the dinosaura the fore limbs become smaller and smaller, the suspicion naturally arises that they may have occasionally assumed the erect position. That suspicion was entertained by Mentell, and was almost demonstrated to be justifiable by your own distinguished anatomist, Dr. Leidy. But the discoveries of late years have shown that in some of these forms it was actually so, that you had reptiles which walked on their two hind legs in exactly the fashion that birds now do ; and I have here in this diagram a representation—a perfectly accurate and faithful representation—of an existing fossil, except for this : that whereas, in the existing fossil the bones are twisted about and out of place, I have put them here in the position which they must have had in nature ; and now you see a creature with a long neck, a light and birdlike head, with teeth, very small anterior extremities, with a slender termination, and the a posteriori limb, which is in almost all respects like that of a bird ; and that creature most assuredly walked about upon its hind legs, bird-fashion. Add to this compsognathus—as its discoverer calls it—add to this creature feathers, and the transition would be complete, for the other characteristics—as the possession of teeth—would, as we see, not separate the creature from the class of birds as we know it.

We have seen that there have been birds having teeth ; therefore the possession of teeth in this compsognathus would present no difficulty in putting it in the class of birds. So far as the character of the skeleton goes, we may fairly say that there needs here little more than feathers—and whether this creature had feathers or had not we do not know—but it needs little more than that to convert the animal into a bird. I have said that there could be no question, from their anatomical structure, that these animals walked upon their hind legs ; and, in fact, there are to be found in the Wealden strata in England gigantic footsteps, arranged in order and method, which, there can be no reasonable doubt, I think, were made by these great dinosauria, the remains of which are found in the same rocks ; and with this view of the possibilities of reptilian structure, knowing now for certain that reptiles existed which walked upon their hind legs and had the general character and aspect of birds, it becomes a very doubtful question whether those tracks in the valley of the Connecticut, to which I have referred just now, and which formerly used to be unhesitatingly referred to the class of birds—it becomes a very great question whether these footsteps may not all have been made either by true reptiles of this dinosaurian character, or whether we should not—and this is a most interesting possibility, if we could get hold of the skeletons of the creatures which made these tracks, some of which are marvellously like bird tracks—whether we should not come upon exactly that series of forms by which in former days the reptile was connected with the bird.

EVIDENCE FURNISHED BY THE ROCKS.

I do not think, ladies and gentlemen, that I need insist upon the value of evidence of this kind. You will observe that, though it does not prove that birds have originated from reptiles by the gradual modification of the ordinary reptile into a dinosaurian form, and so into a bird, yet it does show that that process may possibly have taken place ; and it does show that there existed in former times creatures which filled up one of the largest gaps in existing animated nature, and that was exactly the kind of evidence which I stated to you at starting we are bound to meet with in the rocks, if the hypothesis of evolution be correct.

In my next lecture I will take up what I venture to call the demonstrative evidence of evolution.—*New York Times.*

MR. CROOKES' RADIATION EXPERIMENTS.

THE recent experiments of Mr. William Crookes, F.R.S., upon repulsion resulting from radiation, will still be fresh in the memory of our readers ; and that gentleman's radiometer has already formed the subject of experiment with many photographers. This radiometer, our readers will remember, is a windlass or wheel, turning on a pivot, in a glass case, tiny pith balls at the extremity of the spokes being black upon one face and white on the other. Inside the glass case there exists a vacuum, as nearly as possible, and upon approaching a candle flame or other source of light to the radiometer the wheel swings round with a greater or less degree of velocity. According to the intensity of the light, so the energy of the little instrument responds, and the radiometer was consequently regarded as one of the most accurate of light measurers. Mr. Crookes has since continued to work arduously to discover the true cause of this movement of the radiometer, for he does not seem to have been satisfied with the obvious explanation that it was due to the action of light alone, and he has now published a further communication which solves the problem to a considerable degree. Mr. Crookes tells us that he has derived considerable assistance in his recent investigations from Professor Stokes, F.R.S., who, as most are aware, like Mr. Crookes, was actively connected with the Photographic Society of London in its early days. Working harmoniously together, these gentlemen seem to have brought their labors to a very satisfactory conclusion, and their verdict is, that the force which puts the little radiometer into motion is due to radiation *indirectly*, but not *directly* so. The small residue of atmospheric air which still exists inside the case of the radiometer is the means of setting the instrument in motion, the arms being acted upon by air-currents produced by heat, and thus made to revolve. Indeed, Mr. Crookes, in a short paper which he has communicated to the Royal Society on the subject, thus sums up the matter very tersely. He says : "The evidence afforded by the experiments of which this is a brief extract is to my mind so strong as almost to amount to a conviction that the repulsion resulting from radiation is due to an action of thermometric heat between the surface of the moving body and the case of the instrument, through the intervention of the residual gas. This explanation of its action is in accordance with recent speculations as to the ultimate constitution of matter, and the dynamical theory of gases." Thus Mr. Crookes plainly states that instead of being due to light, the movement of the radiometer is brought about solely by heat rays.—*Photo. News.*

THE ELECTRIC LIGHT.

THE electric light is gradually being adopted in a practical form for the lighting up of factories and warehouses. Hitherto, as is well known, the electric light has been little else than a wonder and an experiment, and the occasions on which it has been practically employed are very rare indeed. At the present moment France appears to be in the van, and we hear of several establishments where arrangements have been made for lighting up with electricity. Last year there were but two examples of this method of illumination to be seen—namely, at the foundry of M. Ducommun at Mühlhouse, and at M. Gramme's factory in Paris. Now the light is daily—or we should say, rather, nightly—employed by Pouyer-Quertier in the Ile Dieu, by Bréguet in Paris, by Sautter, Lemounier & Co., also in Paris, at the sugar-factory in Sarmaize, and in the iron-works at Bessege. Six other firms and establishments in Paris and Lyons are having the apparatus fitted, while the Vienna Opera House employs the electric light, it is said, every evening. The electric current is generated from a magneto-electric machine made upon Gramme's principle, and besides those in France there are now seven such instruments in Russia, six in Spain, five in Austria, four in Italy, six in England, three in Portugal, and four in South America. It will be remembered that we have sent two of these electric light machines with the North Pole Expedition, both the "Alert" and "Discovery" being provided with such means of illumination ; and our iron-clad navy, it is said, is to be provided with similar lamps, to prevent attack from small torpedo vessels under cover of the darkness. It is very satisfactory to know that we have been able at last to apply such a valuable means of illumination for the purposes of every-day life, a problem which has required more than half a century to solve. It was, if we remember rightly, in 1804 that Sir Humphrey Davy first showed the electric light publicly in this country, and yet it is not until the present year that we have begun to adopt the light in factories and workshops. The great advantage of the electric light seems to be that, when once established, the source of light requires little care or solicitude, while its cost is certainly not so great as that of a multitude of gas lamps. Again, there are no unhealthy vapors given off, while the light is so brilliant that you may perform at night the same operations pretty well as in the daytime. Another point of considerable importance is that colors appear the same by electric light as they do by sunlight. Finally, there is no such risk of fire as with gas and candles in large numbers, and the walls and ceilings do not suffer from products of combustion. A hard sort of graphite which is obtained from gas retorts is the material from which the points are manufactured, and so simple is the apparatus that after two or three days' experience any man can take charge of it. It is said that during the past three months as many as thirty machines have been in action, and not a single one has required repair.—*Photo. News.*

MARINE PHOSPHORESCENCE.

PHOSPHORESCENCE is the luminous appearance presented by many substances in the dark, as with stale fish, the live medusæ, or jelly fish ; supposed in the latter case to be occasioned by the reproductive and motory systems from irritation. It continues when phosphorescent fish or salt water are placed in hydrogen, nitrogen, carbonic acid, and air with a trace of ether. It is destroyed by acid and alkaline solutions, alcohol, and ether, while phosphorescent sea water becomes more luminous by ammonia, alcohol, and acids. Among the marvels which excite the admiration of the student of nature, not the least strange is the group of phenomena known under the name of animal phosphorescence. We are so accustomed to associate light with heat, and to consider that fire of some kind is necessary to its production, that the imagination is appealed to with unusual force when we find light proceeding from the body of a living animal. Yet it is well known that the emission of light is not an uncommon characteristic among the members of the invertebrate divisions of the animal kingdom. Travellers have often expatiated on the beauty of the scenes which they have witnessed in the tropics, when the seas or forests have seemed to be illuminated by innumerable sparks of fire ; and recent discoveries have shown that the luminous quality is even more common than was previously supposed. The phosphorescence or luminosity of the sea is the result of sparkles or emission of light from various species of small marine animals. The track of the vessel in many parts of the tropics seems as if strewn with diamonds. In the small channels and harbors on the western and northern coasts of France, each stroke of the oar is attended by very numerous brilliant sparks. In the harbor of Boulogne, on a still evening, I remember being particularly struck with the phenomena. The water when quiet was always perfectly dark, but the least movement drew forth light. A grain of sand cast upon the dark surface of the water produced a luminous spot, and the undulations of the water were so many bright circles. A stone as large as the fist produced the same results in a more intense degree, and moreover each splashing occasioned a scintillation like that of a bar of iron at a white heat when struck upon an anvil. The entrance of a steamboat when the phenomenon was most apparent was a magnificent sight, and recalled to mind the descriptions of travellers. The luminous waves on the shore, seen from a distance, presented a uniform tint of a pale dull white. The mixture of waves as they near the shore, crowned with a light bluish flame, seem, as they reach the bank, to be surges of melted lead or silver, strewn with an infinite number of bright scintillations, either brilliant white or of a greenish tinge. The spectacle is then most beautiful. If I plunged my hands into the sea they became luminous all over, something like the appearance of burning spirits in the amusement of snap-dragon. In filling a glass tube with water, it will be found that these animalcules occupy from one seventh to one half of the space, and from their immense numbers it is easy to understand how the sea, when set in motion, may present a uniform brilliancy. The figures of a watch face or the letters of a book may frequently be read by this light. During the months of February and March the sea of the Bay of Panama is full of phosphorescent animalculæ, which form reddish-colored streaks on the surface. There are various kinds of marine infusoria which render the sea luminous at night, but the principal agent in producing this wonderful and always interesting phenomenon is a minute, almost transparent, vesicle, the place of which has not yet been determined by systematic naturalists, but which is known by the name of *Noctiluca miliaris*. It is a mere bag of transparent membrane, with a slight brownish tint, and under the microscope shows studded with minute points all over the surface. Its form is globose, but slightly two-lobed, with a flexible tentacle by which it slowly sculls itself through the water. Immense numbers of these minute animals are congregated together, and forming patches of a reddish scum at the surface are driven on shore along the

beach by the currents and winds. When dashed by the waves against the rocks, they are broken up, and the empty membranes give the waters of the harbor an appearance as if strewn with dust. When collected in a glass of sea-water, they float on the top. At night, when the glass is shaken, every little vesicle is seen to be illuminated in its interior with a bluish light, and the friction of motion, or against one another, seems to be the exciting cause. Allowed to subside into quietness, the luminous phenomena cease, and on the following morning the vesicles which, when recently taken up, floated at the top of the water, will be found sunk to the bottom, as if they had acquired a greater specific gravity. In the month of March the phosphorescence of the sea about Panama and the islands in the bay is due mostly to the immense diffusion of microscopic jelly fishes, barrel-shaped (ctenophora) and equally minute shrimp-like crustaceans. To bathers in the sea at this period of the year, the water acts on the skin like nettles, and an attack of urticaria is more likely to be induced than the refreshing effects of the reduced temperature of the sea (sixty-eight degrees), which is contemporaneous with the phosphorescent phenomena under consideration. Why the lowest class of animals only have been endowed with the power of emitting light and electricity is a curious consideration.

HOW TO BUILD CHEAP BOATS.

By PADDLEFAST.

NO. VIII.—A THIRTY-DOLLAR YACHT. LENGTH, 18 FEET.

THIS boat is designed for sailing only. It is decked, and furnished with a centreboard. The sail is "catrigged," and therefore more convenient than the foregoing. This boat will carry 8 persons, and with that load the draught is 10 inches. The approximate cost of materials, including sail, cordage, anchor, etc., is $30.

CONSTRUCTION.

After observing the dimensions for the two previous boats, the builder can easily judge of the proper size of timbers for this boat. It is 18 feet long from the junction of apron and stem to the inner surface of stern-piece. The keel is flat, 1.5 inch thick, and 10 inches wide at ⊕. The yacht bow is shown in Fig. 70, with a pine "step," Q, 1.5 inch thick, resting on the deadwood at one end and on the keel at the other, and as broad as the outer planking will permit. Into a square mortise cut through it, about 1 foot abaft the stem, the mast is fitted with a shoulder. Of course rib H is better secured by nailing it to this step. As this boat is to carry far more sail than the others, the step should be firmly bolted.

Lines I., II., III., etc., are 4.2 inches apart on the working drawing

Table 1.

	0.	I.	II.	III.	IV.	V.	VI.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
Rib ⊕.	7.05	18.56	28.39	35.61	39.48	41.16	41.66
" A.	7.05	18.06	27.30	33.98	37.88	39.64	40.40
" B.	6.84	16.03	24.94	31.16	34.98	37.12	38.13
" C.	6.30	14.28	21.25	26.71	30.40	32.92	34.52
" D.	5.37	11.34	16.92	21.56	25.08	27.68	29.65
" E.	4.36	5.13	12.76	16.12	18.90	21.25	23.96
" F.	3.56	6.21	8.82	11.	13.10	14.95	16.63
" G.	2.35	3.65	5.12	6.46	7.81	8.98	10.08
" H.	1.42	2.01	2.52	3.02	3.52	4.11	4.70
" 1.	7.05	17.97	27.08	35.11	39.31	41.07	41.66
" 2.	6.80	16.12	25.68	33.18	38.09	40.22	41.34
" 3.	6.46	13.94	23.20	29.88	35.61	38.72	40.23
" 4.	5.46	11.17	17.79	24.09	30.90	35.70	38.01
" 5.	4.11	8.4	13.44	19.23	25.70	31.56	35.07
" 6.	2.85	5.90	8.88	13.35	18.98	25.62	31.08
" 7.	1.08	1.08	3.99	7.22	11.84	18.14	25.30
Stern..	....	....	....	....	3.36	8.82	17.29

Table 2.

Rib ⊕	26.79 in.
" A	27.21 "
" B	27.89 "
" C	28.89 "
" D	30.57 "
" E	32.67 "
" F	35.02 "
" G	37.80 "
" H	40.65 "
Stem	42.92 "
Rib 1	26.03 "
" 2	26.71 "
" 3	27.13 "
" 4	27.88 "
" 5	28.81 "
" 6	30.15 "
" 7	31.33 "
Stern	32.84 "

Table 3.

Rib ⊕	41.66 in.
" A	40.57 "
" B	38.43 "
" C	35.36 "
" D	31.24 "
" E	25.95 "
" F	19.65 "
" G	12.76 "
" H	6.13 "
Stem	....
Rib 1	41.66 "
" 2	41.57 "
" 3	40.48 "
" 4	38.55 "
" 5	33.37 "
" 6	33.60 "
" 7	30.40 "
Stern	26.79 "

The stern is 1.4 inch thick. The whole framework, excepting ribs, is heavier than any before.

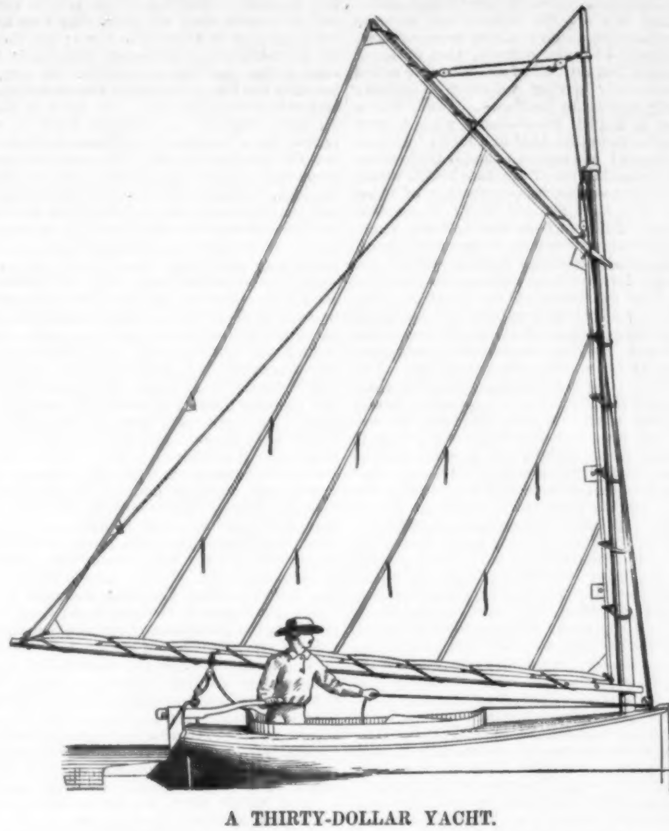
The stern is 13.6 inches above the keel. Bottom of rib 7, 4.2 inches above keel; and bottom of rib 6, 2.8 inches.

The widths of the upper surface of keel are given in column 0, Table 1. The widths at ribs 6 and 7 are for the upper surface of the stern deadwood, for the deadwood extends to rib 5. The aft edge of the stern-post is 1 inch wide, tapering to ½ at keel.

The stem tapers to 5 inches wide at cutwater, and is bound by an iron strap.

Dimensions of Ribs.

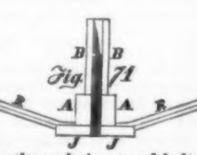
	Length.	Thickness.	Width at upper end.	Width at lower end.	Bevel at upper end.
		Inch.	Inch.	Inch.	Inch.
Rib ⊕.	Can be found from the working drawing.	.5	.5	1	..
" A.		"	.5	"	..
" B.		"	.56	"	.06
" C.		"	.59	"	.09
" D.		"	.61	"	.11
" E.		"	.65	"	.15
" F.		"	.69	"	.19
" G.		"	.71	"	.21
" H.		"	.72	"	.22
" 1.		"	.5	"	..
" 2.		"	.5	"	..
" 3.		"	.54	"	.04
" 4.		"	.56	"	.06
" 5.		"	.58	"	.08
" 6.		"	.60	"	.10
" 7.		"	.62	"	.12
Stern		....	....	....	.13



A THIRTY-DOLLAR YACHT.

Rib	7 is 10.8	inches from	Stern.
"	6 " 11.4	" "	Rib 7.
"	5 " 12.	" "	" 6.
"	4 " 12.6	" "	" 5.
"	3 " 13.2	" "	" 4.
"	2 " 13.8	" "	" 3.
"	1 " 14.4	" "	" 2.
"	⊕ " 14.4	" "	" 1.
"	A " 14.4	" "	" ⊕.
"	B " 14.4	" "	" A.
"	C " 14.4	" "	" B.
"	D " 13.8	" "	" C.
"	E " 13.2	" "	" D.
"	F " 12.6	" "	" E.
"	G " 12.	" "	" F.
"	H " 11.4	" "	" G.

A cross section of the well is shown in Fig. 71. J J is the keel, A A the two lower pieces of the sides of the well, 2 inches thick; B B are the two upper pieces, which need be but 1 inch thick. The end pieces, to which these are nailed, extend through the keel. A A are nailed to the end pieces and bolted to the keel, through and through, before B B are applied. Between A A and the keel, before the former are fastened, strips of flannel are laid, saturated with fresh paint. Flannel and paint are applied between the sides of the trunk and the end pieces also. All the ribs R R, which occur in the length of the well, are nailed at the ends to the keel, without bottoms. The deck beams are placed one 4 inches forward of every frame, omitting H; but the deck beam before C is put 2.6 inches forward of the latter, and at this deck beam is the forward end of the well. The height of the well is such that this deck beam rests upon it, and is bolted to the end piece of the well. The length of the well is 5 feet. The space between sides is 1.2 inch. A A and B B are cedar; the end pieces yellow pine.



board through which the mast passes is about 9 inches wide and 1 inch thick. The deck boards are fitted against, not over, the upper strake, and they are flush with the upper edge of the stern-piece also, and nailed upon a cleat attached to the latter, as the seat-boards are, in Fig. 53.

The boards of the ceiling fit closely. There is a movable portion at E, for bailing. D D are the benches. The cockpit is 57 inches wide at ⊕, and extends from forward end of well to the deck beam at frame 7.

The cockpit divides many of the deck beams, but the simplest plan is to cover the whole boat with deck beams, one about 4 inches forward of each frame, as though there were to be no cockpit; then nail on the deck boards, marking the oval, and saw out the oval through the deck beams. Nail narrow rabbetted cedar boards in a vertical position entirely round the oval, as shown by Fig. 75. The lower ends are nailed to cleats *a* on the ceiling; the upper ends project about 3 inches above the deck, forming the combing. The boards are nailed also to the edges of the deck boards and to the ends of the deck beams. Apertures are cut on each side of the centreboard for access to the space under deck. A cuddy in the stern is convenient.

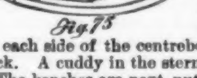
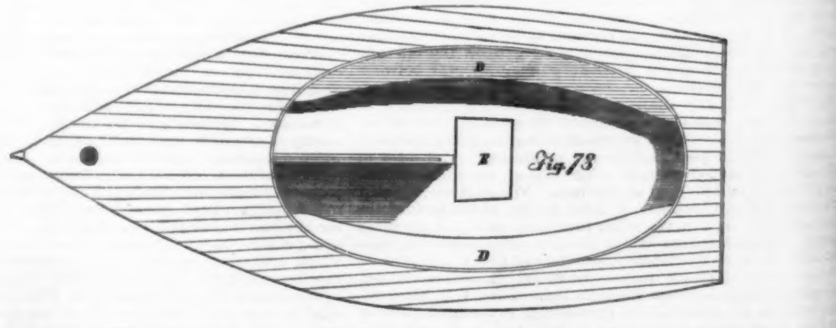


Fig. 75

The benches are next put in, placed upon occasional cleats, *b*, Fig. 76, and supported at half length by a stanchion. To give finish and strength to the combing, an oak moulding, *c*, is nailed to the edge outside.

Sail, duck; 15.5 feet high on mast; peak 6 feet 9 inches abaft mast on horizontal line, 25 feet above boom on vertical line. Length on boom, 20 feet 3 inches. Rise, 2.5 feet. Mast, 28 feet 7 inches long, 4 inches diameter at butt, 1.5 at head. The wood for the spars should be either spruce or pine. As the cut of complete yacht shows,



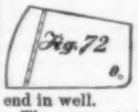
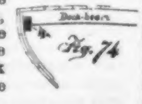


Fig. 72 shows centreboard with iron work. It swings on an iron bolt running through 0. Height at aft end, 42 inches; at forward end, 31 inches; cedar, .75 inch thick. Length such as to give .5 inch play at each end in well.

The upper strake in this boat is cedar, like the other planks, and there is no gunwale. The ends of the deck beams are let into a rising, W, Fig. 74, nailed to the ribs half an inch below the edge of the upper strake. The ribs are sawn off flush with the rising, and the deck boards laid against the upper strake. The rising is 1 × 2 inches.



The deck beams are .8 inch thick and 2.2 inches deep. The curvature is such that the middle point of deck beam at frame C is 4 inches higher than the ends. Same curvature for the others.

Fig. 73 is the deck plan. The deck boards are represented narrow, about 2 inches wide, so that when they shrink, as they must under hot suns, the seams may not open so wide. They are yellow pine or cedar, .5 inch thick. The

the halliards are trained aft and belayed to cleats on the inside of the combing forward. The traveller is screwed to the upper edge of the stern-piece. Attention is called to the new method of bending the sail on the boom. The only other objects shown in the engraving which have not been made familiar are the "gaff," which supports the peak, and is merely a miniature boom; and the "topping lift," a rope running from the masthead to the end of the boom. Its only object is to partially support the boom.

Length of rudder, 24 inches. It may be made as in Fig. 28, but a neater head is made of sheet-iron bent to form the mortise. Length of tiller, 30 inches.

If this yacht is used in salt water, it is quite desirable to use some paint on the bottom which will prevent the formation of barnacles and grass. Copper paints are sold which are as effective as sheathing, but beware of worthless imitations. Paris-green paint is partially successful.

Sand bags are the cheapest and handiest ballast. When empty they are about 14 inches long by 9 inches wide. The material used is duck; a rope handle is sewed to one side. They should be filled with gravel, not sand, for the latter rots the bag. About ten are needed for this boat.

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